SUBARU
Body Repair Technical Skills Handbook

Introduction

This manual sets out know-how required to carry out auto body repair for those wanting to acquire auto body repair skills through to those already engaged in repair work in the course of their jobs.

It goes without saying that knowledge, a sense for the work and practical know-how acquired through practical experience are important when acquiring expertise in body repair. However, at a time when advances to the quality of materials, construction and assembly precision used in vehicles are improving at an almost daily rate, gaining a firm understanding of basic knowledge is essential for carrying out effective and reliable repairs of a quality that will meet with customer satisfaction.

This handbook will first describe basic knowledge of health and safety, vehicle body construction, and then cover the basic procedure step by step from external panel repairs and underframe repairs, to the replacement of welded panels, providing general examples.

SUBARU

Subaru · Body Repair Technical Skills Handbook

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Chapter 1 Health and safety measures

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1. Safety measures at work

Various kinds of machinery, equipment, tools and materials are used in body repair work. Body repair involves highly dangerous work, including the generation of intense heat and strong light when welding and fusing, dust and fires during sanding, and the handling of panels and parts with sharp edges. To protect oneself and prevent accidents, it is important to learn about safety measures and to wear protective gear suitable for each task.

① Follow the prescribed methods for using equipment, machine tools and materials.
② Use the correct equipment, machine tools and materials for each task, and do not use equipment for tasks for which they are not designed.
③ Regular maintenance of equipment and machine tools and maintenance after use, depending on what they are used for, must be carried out (checks, cleaning, lubrication as necessary, etc)
④ Maintain a suitable body posture and use necessary supports.

2. Use of protective gear

The following protective gear is used when carrying out panel work.

(1) Clothing

When engaged in welding work where sparks are generated, wear a welding apron and arm and leg protectors. Do not wear short-sleeve summer clothing when welding.

(2) Head gear

Head gear must be worn at all times for protection from sparks, iron powder, dust, etc. If the visor gets in the way due to the site you are working on or because of other protective gear you are wearing, don't remove your head gear but wear it backwards.
It is recommended that helmets be worn when doing body work.

(3) Safety boots

Safety boots prevent slipping, the thick soles protect the soles of your feet from sharp objects, and the steel caps protect toes from heavy objects. The surface is resistant to sparks and other hazards.

(4) Safety glasses

There are safety glasses that prevent dust from getting into the eyes and auto-darkening helmets worn when welding. Safety glasses protect the eyes not only from paint and body filler dust, but also from metal powder when cutting panels and from sputters when stud or spot welding. The rim adheres to the skin, thus preventing dust and other matter from getting inside.
When MIG welding while making body repairs, use a welding helmet and not an auto-darkening helmet.

(5) Dust masks

Wear a dust mark so you don't breathe in paint, dust particles, metal power or welding fumes.

Dust masks are mainly worn when using body filler following panel work. There are masks that contain activated carbon.

Replace with a new one when use reaches the time limit for use.

(6) Face shields

Faces shields protect the face from metal power and from sputters when welding. Although safety glasses seal tightly, dust can get into the eyes through gaps. This risk is lowered by using a face shield and safety glasses together.

Some face shields also serve as welding masks.

(7) Welding helmets (auto-darkening helmets)

Welding helmets protect the eyes and face from strong light and ultraviolet light when MIG welding. There is a hand-held type and a type worn on the head.

There are also auto-darkening welding helmets that use a liquid crystal filter.

(8) Ear plugs (ear muffs)

Ears should be protected from loud noise, such as the noise of hammering, the setting and re-setting of equipment, and cutting noise when using air tools to cut panels. If ear protection is not used when engaged in repair work for long periods, noise and wavelengths not audible to the human ear can harm hearing, and in some causes cause deafness.

There are ear plugs that are easily inserted into the ears, and ear muffs that cover the ears.

(9) Gloves: Work gloves (heavy cotton), welding gloves, gloves for handling solvents, high voltage insulating gloves

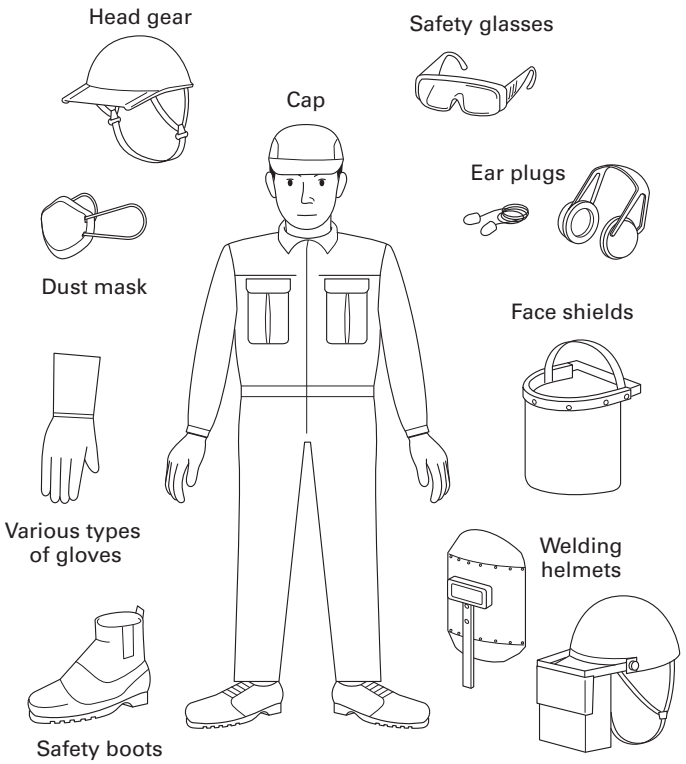
Wear gloves appropriate for the particular task. Use heavy cotton gloves when performing general tasks. There are slip-prevention cotton gloves that have a rubber coating on the palm side, and high-strength gloves that use Kevlar protection.

Avoid using cotton gloves when drilling because the tips can get caught.

Gloves made from animal skin are suitable when welding or repairing the underframe.

There are also solvent resistant gloves for use when handling degreasing agents and paint, and special rubber gloves for use when working on high voltage sites.

■ Use of protective equipment



3. Precautions

(1) Protect bodywork and interior and exterior fittings

Bodywork can be smudged and scratched during body repair work. Prevent this by protecting the area around the work site. Use a sheet or a special protective cover.

1) Prevent dust when sanding using a sander, etc.

Prevent areas beside the repair site from being dirtied by dust generated when sanding paint or body filler. Be particularly careful with regard to the passenger compartment and engine bay. Protect the surrounding area using sheets, covers and masking materials.

2) Prevent interior fittings from getting dirty

Prevent dust from adhering to the seats, steering wheel and other parts of the passenger compartment by protecting them with plastic sheets and covers.

3) Prevent sparks during welding

Protect the vehicle body from sputters and sparks during welding by covering it with fire-proof sheets (cloth and paper).

4) Protect the surrounding area when making body repairs and treating the substrate.

When making body repairs or treating the substrate, protect the surrounding area by attaching masking tape or plastic tape so that the sander does not damage the pinstripe or other nearby parts.

(2) Prevent fires and explosions

Many pieces of equipment used for body repair can easily catch fire or explode. Be extremely careful when handling such items.

1) Gasoline

When siphoning gasoline, be sure to comply with fire regulations. Work in an area with good air flow and warn nearby workers. Do not use a plastic pump or tank that generates static electricity when siphoning or for storage. Store the siphoned gasoline in a specified safe storage place.
If gasoline leaks onto the floor of the workshop, do not leave it but wipe it up straightaway.

2) Paints

With the exception of water-based paints, most paints are flammable. Store them in a specified place and do not leave them lying around elsewhere. As an environmental protection measure, always secure lids and caps to prevent the evaporation of volatile organic compounds.
Also be careful when disposing of leftover body filler, cloths containing organic solvent-based degreasing agents and used paint cans, as there is the risk of spontaneous combustion.

* Volatile Organic Compounds

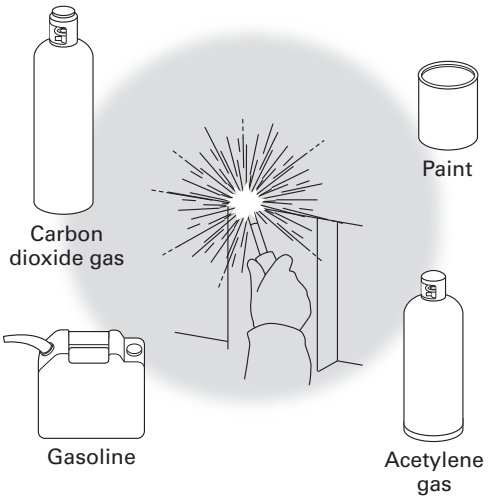
3) Gas cylinder

Be careful when handling acetylene gas, oxygen gas, carbon dioxide gas, argon gas, etc used when welding and also watch out for hose deterioration and the aging of equipment.

4) Naked flames and other fire sources strictly prohibited

Welding sparks can cause flammable gases to explode when gases reach a specified concentration within an enclosed space. Therefore, do not bring any fire sources into the workshop, except those required for work.
Smoking is prohibited while working. Use a specified smoking area.

■ Many pieces of equipment used for work are highly dangerous



(3) Health and safety related to body repair

1) Body repair work

Body repair and welding work are highly dangerous tasks.

Body repair work can cause serious damage or injury due to the heavy items and large force handled. Pay attention to the following to prevent serious damage or injury.

① Securely fasten bolts, nuts etc on repair equipment and check they are not loose.

② When pulling, be prepared in case the clamp should come off by staying out of the area where the chain or clamp is likely to land. Attach a safety wire so that the clamp is restrained if it comes off.

③ Follow instructions for the use of jacks and hoists carefully, and when going under a vehicle always support the vehicle securely with rigid racks, etc.

2) Using jacks

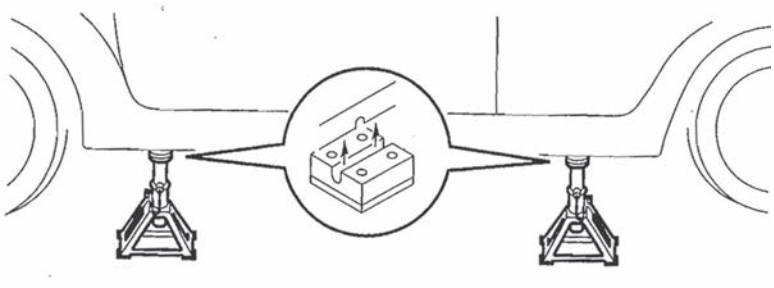
When jacking up a vehicle or supporting a vehicle with rigid racks, follow the instructions and weight limits in the service manual.

Check carefully to see whether the vehicle is stable or not.

When jacking only the front or rear, make sure that the wheels are locked.

Do not leave a vehicle in a jacked up position.

■ Vehicle is jacked using rigid racks



3) Welding work

Providing that there is nothing wrong with a welder it will not cause electric shocks or catch fire. However, regular checks are essential.

Pay attention to the following when welding.

① Gas produced when welding is toxic so wear a protective mask.

② Looking directly at a flame when welding can, at worst, lead to the risk of blindness. Always wear a welding helmet or safety glasses.

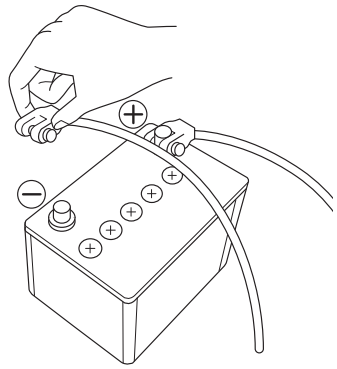
③ When using an oxygen or acetylene gas welder, check there are no flammable items in the surrounding area, as these welders produce naked flames.

4) Electrical work

When doing wiring or other electrical work, make sure the ignition switch is turned off and remove the connector to the negative terminal on the battery.

If there is a risk of the generation of static electricity, do not touch the control unit, connector or other similar parts. Either use an anti-static electric cord or start work after removing the static electricity by touching earthed metal.

■ Remove the connector from the negative terminal on the battery before starting work



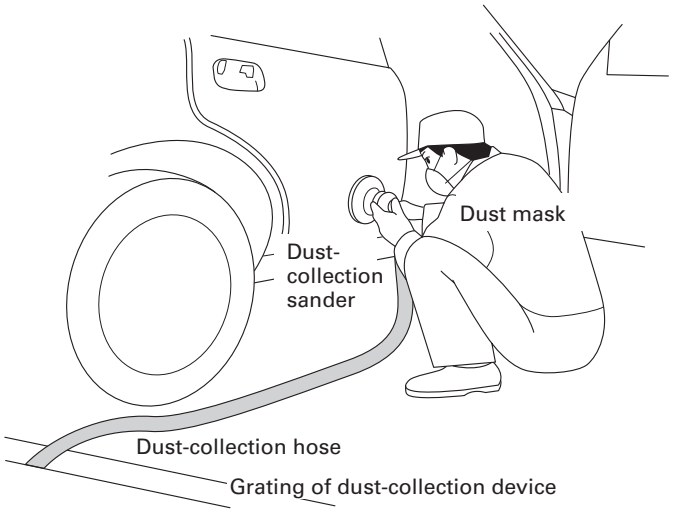
(4) Health and safety related to painting work

1) Body filler

Coming into contact with sanding dust produced when applying body filler after body repair harms respiratory function, causing pneumoconiosis etc. Use a dust mask when applying body filler. Also use a sander that collects dust. However, since the use of a dust-collection sander alone will not completely take care of the body filler dust, work in a place with a dust collection system that suctions dust from the floor and wall surfaces.

When cleaning after sanding, wear a dust mask and lower the pressure of the duster gun used for blowing so that the dust does not scatter over a wide area.

■ Be careful with dust when using body filler

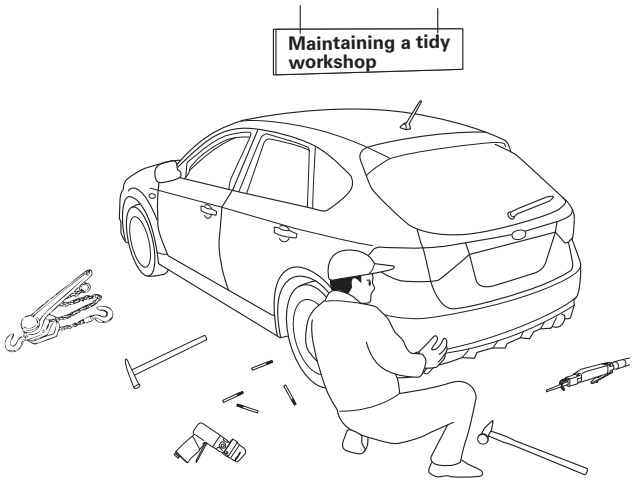


4. Maintaining a tidy workshop

A tidy workshop is the first rule of safety. All equipment, tools and materials should be stored in a pre-determined place, and returned to their original places after use. Leaving machine tools and materials on the workshop floor is very dangerous, as you can easily trip over them.

Arrange the items you will need in a tool cart beforehand, place the cart near the vehicle you are working on and take the items from the cart and put them back while working. This prevents machine tools from cluttering up the floor. It also makes for more efficient work.

■ Being tidy prevents dangerous situations



It's easy to trip over tools left lying on the floor

Chapter 2 Body construction

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1. Passenger Vehicle Frames

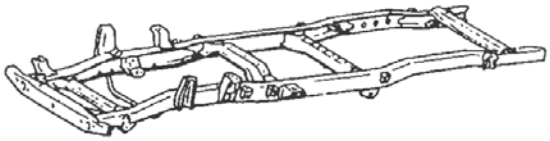
A monocoque body structure is adopted in passenger vehicles, where there is a single frame that supports the body, engine and suspension and absorbs force while the vehicle is in motion.

There are other frames with a variety of structures besides the monocoque body. They are broadly divided into the following.

(1) Ladder-type frame

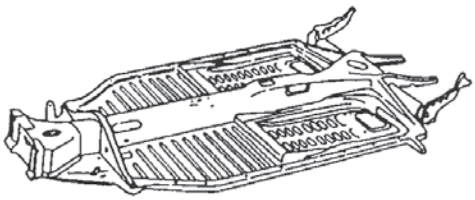
Two parallel rails are joined by cross members, and as the name suggests it is a simple structure in the shape of a ladder. This frame is used for trucks and 4-wheel drive vehicles. This is also called a ladder frame.

They are mainly used in passenger vehicles because they allow a large passenger compartment and have a low perimeter frame.



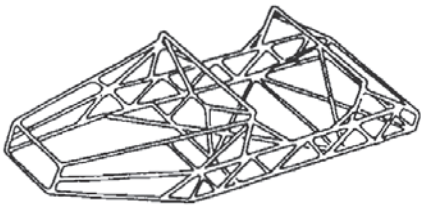
(2) Platform frame

This frame's structure has robust floor panels that serve as the frame.



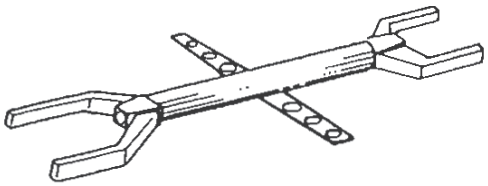
(3) Space frame

This frame is made up of pieces of tubing. With a shape like that of a motorbike frame, the complex structure is not suited to mass produced vehicles.



(4) Backbone frame

With a spine in the center, like the space frame this backbone frame is suited to small production sports cars.



2. Characteristics of the unitized body

An egg is an example of a shell-type structure, which can withstand a considerable amount of force when applying force using a finger on the top or bottom. This is because the force is not concentrated but is absorbed by the entire exterior of the shell. Called stressed skin construction, it is used in the design of aircraft.

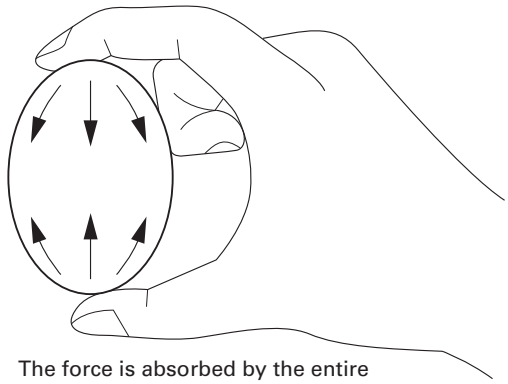
Like an egg shell, the outer skin made of a uniform material spreads force applied to one part across the entire body, thus maintaining strength.

Because a vehicle body has opening parts like doors and the engine bay, pillars and members are used to ensure strength. Since the amount of force received differs from site to site, strictly speaking this can't be called a unitized structure.

In Japan this is referred to as a "monocoque" body, whereas overseas it is called a unitized body or frameless body.

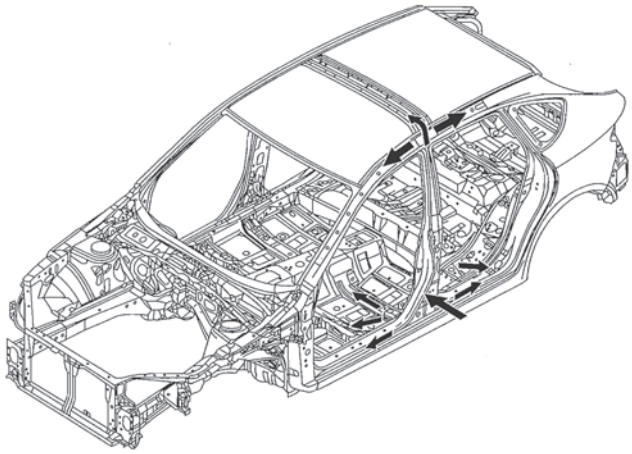
In a unitized body the underframe is made of closed section members and the heavy engine, suspension, steering, etc are attached directly to the underframe. One notable feature of this type of construction is that it allows the use of panels that are thinner than a frame. This is a good structure from the point of view of its light weight, impact safety, and mass producibility.

■ Egg shell has a stressed skin structure.



The force is absorbed by the entire exterior of the shell.

■ A vehicle is not really like an egg, as it has many opening parts.



3. Rigid and truss structures

The frames of ordinary buildings have a rigid structure and a truss structure. Beams and perpendicular members form a quadrangle, which form a house or building when supported by pillars. In a rigid structure, the contact points have rigid joints.

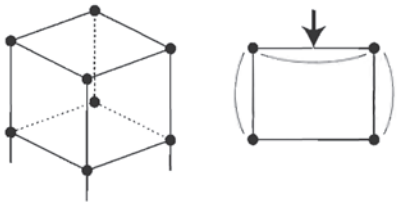
A rigid joint is a joint that has been welded so that it can't move.

A truss structure has a triangular shape like that seen in steel bridges. In a truss structure, the contact points are sliding joints. Sliding joints are joints that move and slide, and reinforced braces are inserted on the diagonal to ensure safety. This creates triangular layers like those in steel bridges.

As a two-dimensional flat surface, when strong force is applied from above, the four corners not only deform outward on the rigid joints of the rigid structure, but the right and left members also deform. However, in a truss structure that is connected with sliding joints, only the upper members deform and absorb the force.

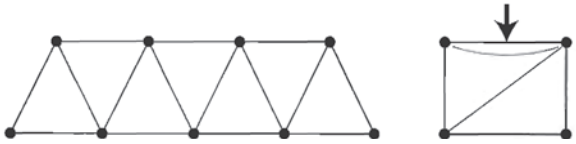
The body of a vehicle is not a closed external wall like an aircraft with a shell structure, as the underframe is made up of a combination of panels with many opening parts. The passenger compartment in the middle has a rigid structure, as well as a shell structure in which the entire frame can distribute the absorption of external force. The front and the rear each have a rigid structure, and building on top of this forms the body's (chassis) unitized structure.

■ Rigid structure



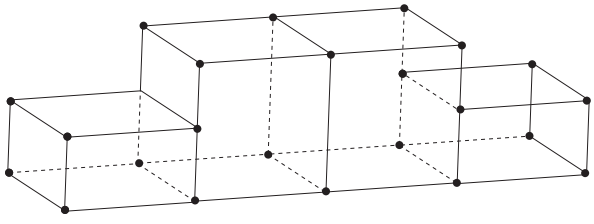
Structure assembled by fixing (rigid joints) members
Example: Buildings

■ Truss construction



Structure assembled (flexible joints) so that members can rotate
Example: Steel bridges

■ A vehicle body is a series of rigid structures



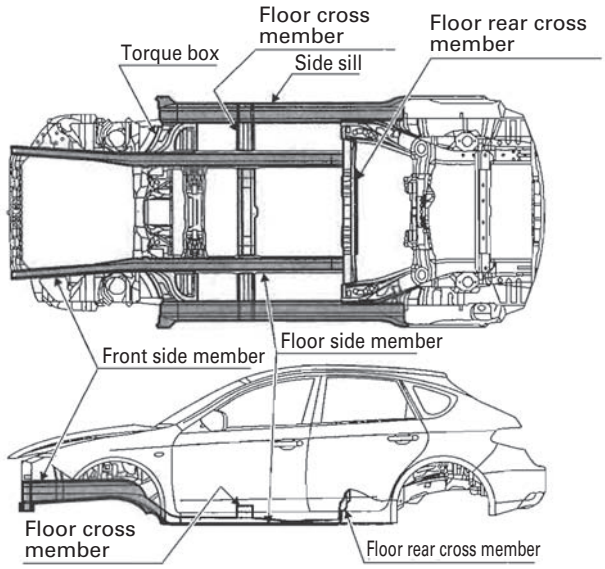
4. Features of the crash safety body

A vehicle body does not only have to be strong, but when it receives an impact in an accident, for example, its structure must be such that as much as the impact force as possible is not transmitted to the passengers. Bodies designed taking this in account are called impact absorption structures and crash safety bodies.

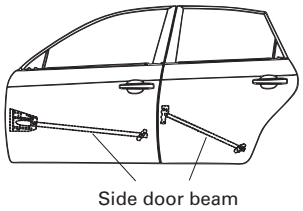
Special design features are included in an impact safety body.

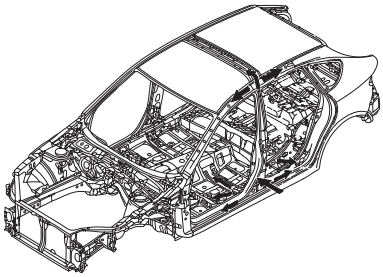
One is disintegration of the part that receives the impact as a means of absorbing the force. Of course, this does mean that the structure is such that the entire body simply disintegrates. Sections that concentrate stress are put in the underframe structure at the front and rear of the body. The structure has sharp curves, a crinkle pattern, and open punch holes. These "impact zones" disintegrate as they were designed to do when the body receives an impact.

■ Structure absorbs energy from the front



■ Structure absorbs energy from the side





5. Structure of body sections

(1) Front body

Heavy parts integral to vehicle motion, such as the engine and transmission, are found in the front body. They must support the force received from the front wheels via the suspension. In front-wheel drive vehicles, the front body also takes the weight and drive force of the differential gear and drive shaft. Consequently, members and reinforcements have a dual hanging rack structure, and the various joints also have a robust structure made by adding reinforcement. The underframe members of front-wheel drive vehicles are thicker than those of rear-wheel drive vehicles, and sometimes the toeboard joints have complex shapes.

The role of the front side frame is to absorb and distribute energy upon impact.

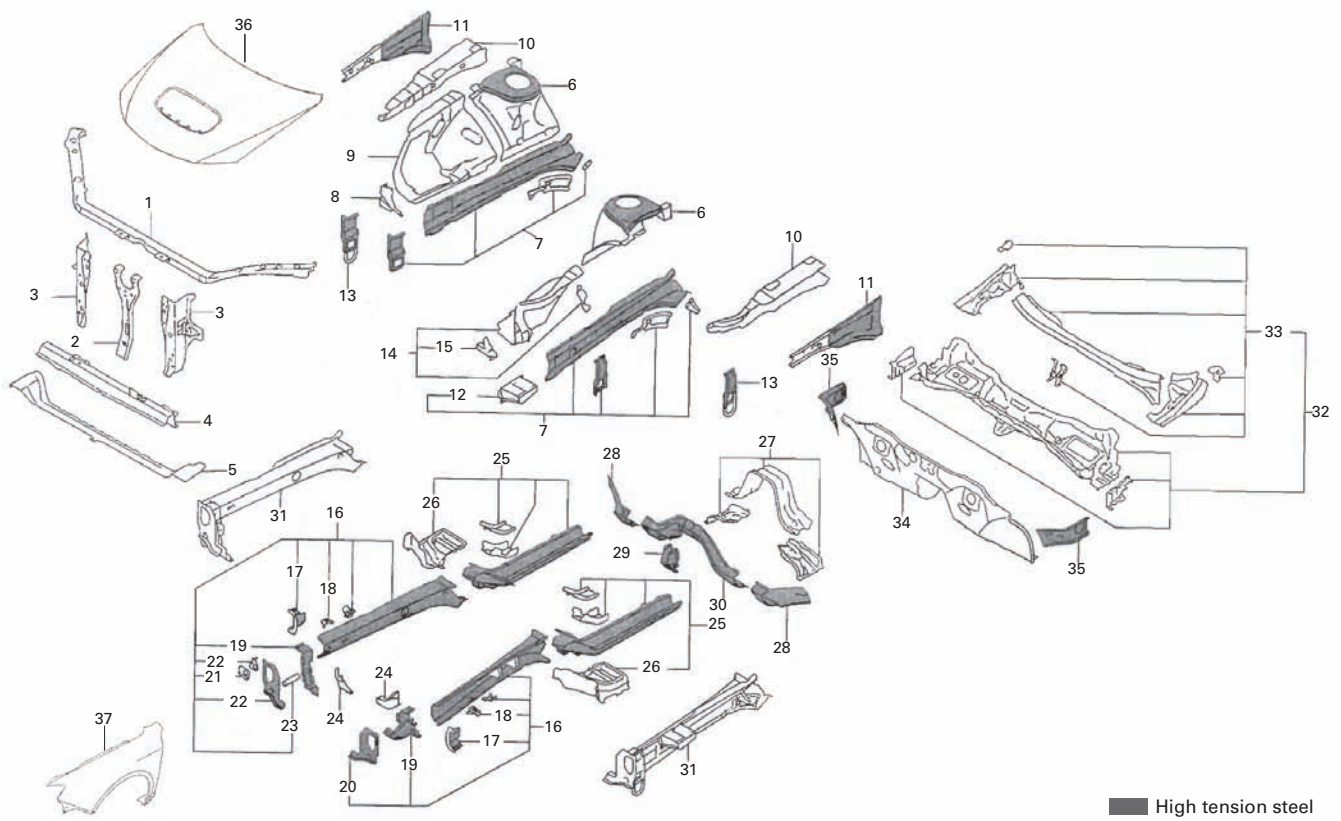
The front end has a significant amount of open space for the mounting of the radiator and headlamps. Cross members are fitted underneath and rather detailed upper members above the front end.

At the sides there are lower side members underneath that support the engine and suspension, and from the wheel apron it is covered by the suspension brackets, which are fitted above the shock absorbers. The upper member is incorporated and reinforced above the apron parallel to the upper member.

There is a toeboard connected to the floor on the passenger compartment side of the front body. Members and reinforcements are welded and take up a large area, and are combined with reinforcing materials. In front-wheel drive vehicles, attachment rigidity is enhanced by placing side members from the bottom of the toeboard to the floor. In some cases a sandwich structure using asphalt sheets is used to effectively absorb engine noise and vibration.

The bolted on hood and front fender have minimal effect on strength. However, the shape and structure of the hood have changed recently to protect pedestrians when collisions occur.

Front body structure and parts



1. Upper radiator member
2. Hood lock stay
3. Radiator side stays
4. Lower radiator panel member
5. Lower radiator member
6. Front suspension bracket
7. Closing plate
8. Right fender bracket
9. Right front wheel apron
10. Upper front wheel apron
11. Upper side member
12. Battery bracket
13. Front tie-down
14. Left front wheel apron
15. Left fender bracket
16. Front side front member
17. Front bumper bracket
18. Spacer
19. Front member gusset
20. Front of front member blade
21. Plate A
22. Plate B
23. Hook pipe
24. Front member gusset C
25. Rear front side member
26. Toeboard reinforcement
27. Front floor cross member
28. Toeboard side cross member
29. Pitching stopper bracket
30. Toeboard center cross member
31. Side member
32. Front panel and duct
33. Front panel
34. Toeboard
35. Gusset
36. Hood
37. Front fender

(2) Center body

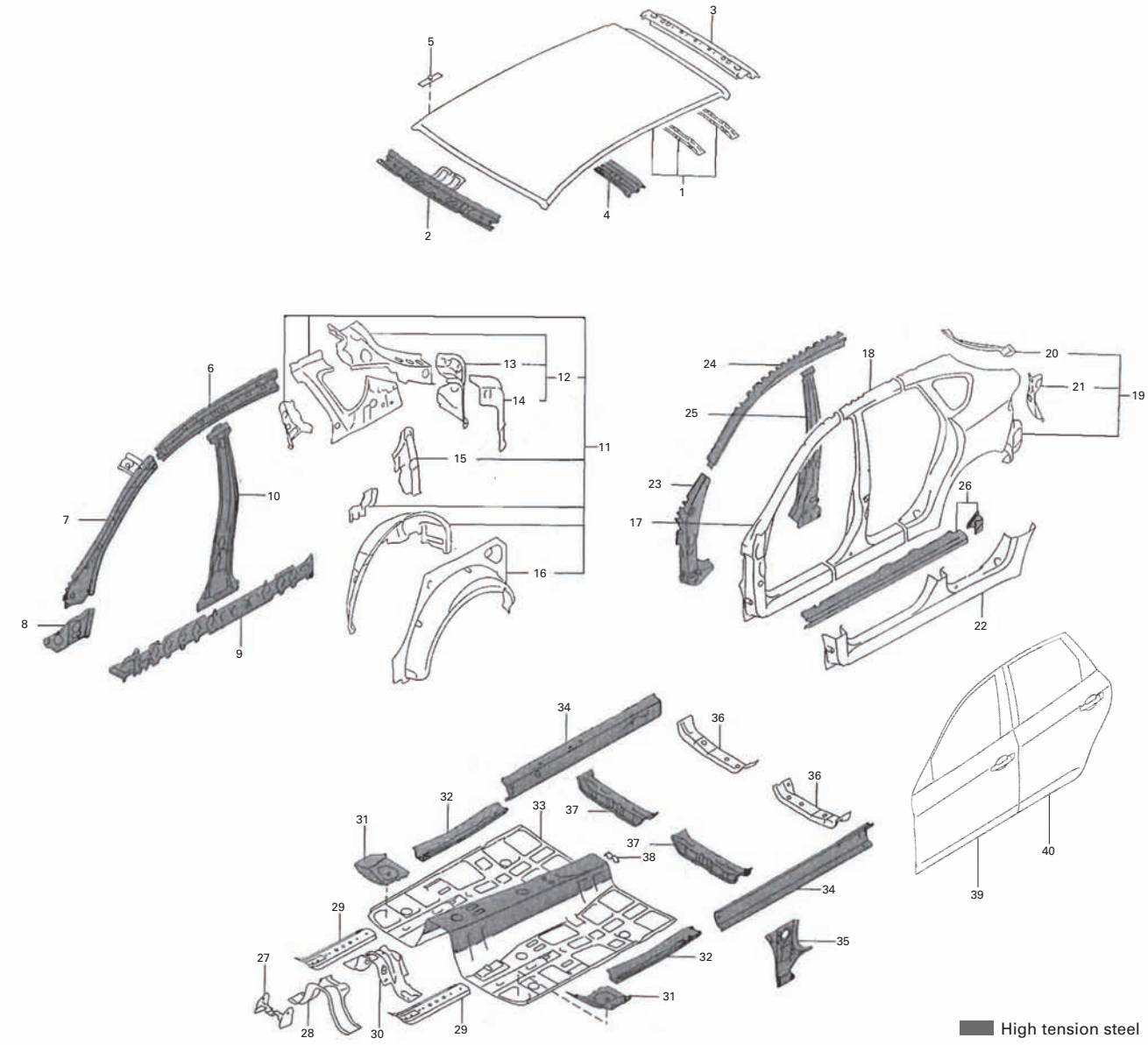
The center body is the passenger compartment used for passengers and goods. The interior space is like an empty box, as there are no structures that have to be installed transversely from right to left or top to bottom. With doors and windows, a large area of the center body opens.

As a result, there are pillars that extend vertically from the floor panel to support the roof panel. The number of pillars is determined by the number of doors. There is a raised floor tunnel running from front to back in the center and a box-section side sill on both sides that supports the weight of the passengers and cargo.

The sides are the same thickness as the doors. It is not possible to construct an impact absorbing structure like that used at the front or rear. As a result, each pillar has a closed cross section structure with and outer and inner panel, and a three-layer structure is created by disposing reinforcements between the panels. Reinforced panels are used to provide a robust structure for hard top bodies and convertibles that do not have a center pillar.

Mechanisms to raise and lower the windows and to lock the door are contained inside the doors, and side door beams are adopted to enhance impact safety when a side impact occurs. This reduces the amount of deformation when the door receives impact.

Center body structure and parts



1. Roof panel
2. Front roof rail
3. Rear roof rail
4. Roof center brace
5. T-stud plate
6. Side rail inner
7. Front pillar upper inner
8. Front pillar center inner
9. Side sill reinforcement inner
10. Center pillar inner
11. Rear quarter inner
12. D-pillar reinforcement assembly
13. D-pillar inner
14. D-pillar reinforcement
15. Rear quarter center reinforcement
16. Rear arch inner
17. Front pillar outer
18. Center pillar outer
19. Rear quarter outer
20. D-pillar extension
21. Rear quarter end
22. Side sill outer
23. Front pillar door reinforcement
24. Side rail reinforcement
25. Center pillar reinforcement
26. Side sill reinforcement outer
27. Instrument panel bracket
28. Floor center cross member
29. Front floor front member
30. Floor rear cross member
31. Toeboard upper reinforcement
32. Front floor rear frame
33. Front floor pan
34. Side sill inner
35. Front pillar lower inner
36. Front seat rear cross member
37. Front seat front cross member
38. Hand brake reinforcement
39. Front door
40. Rear door

(3) Rear body

The structure of the rear body differs according to whether or not there is a trunk lid. Although the structure is similar to the structure of the front body, there is a floor panel covering the bottom. It incorporates the same impact absorption structure as the front.

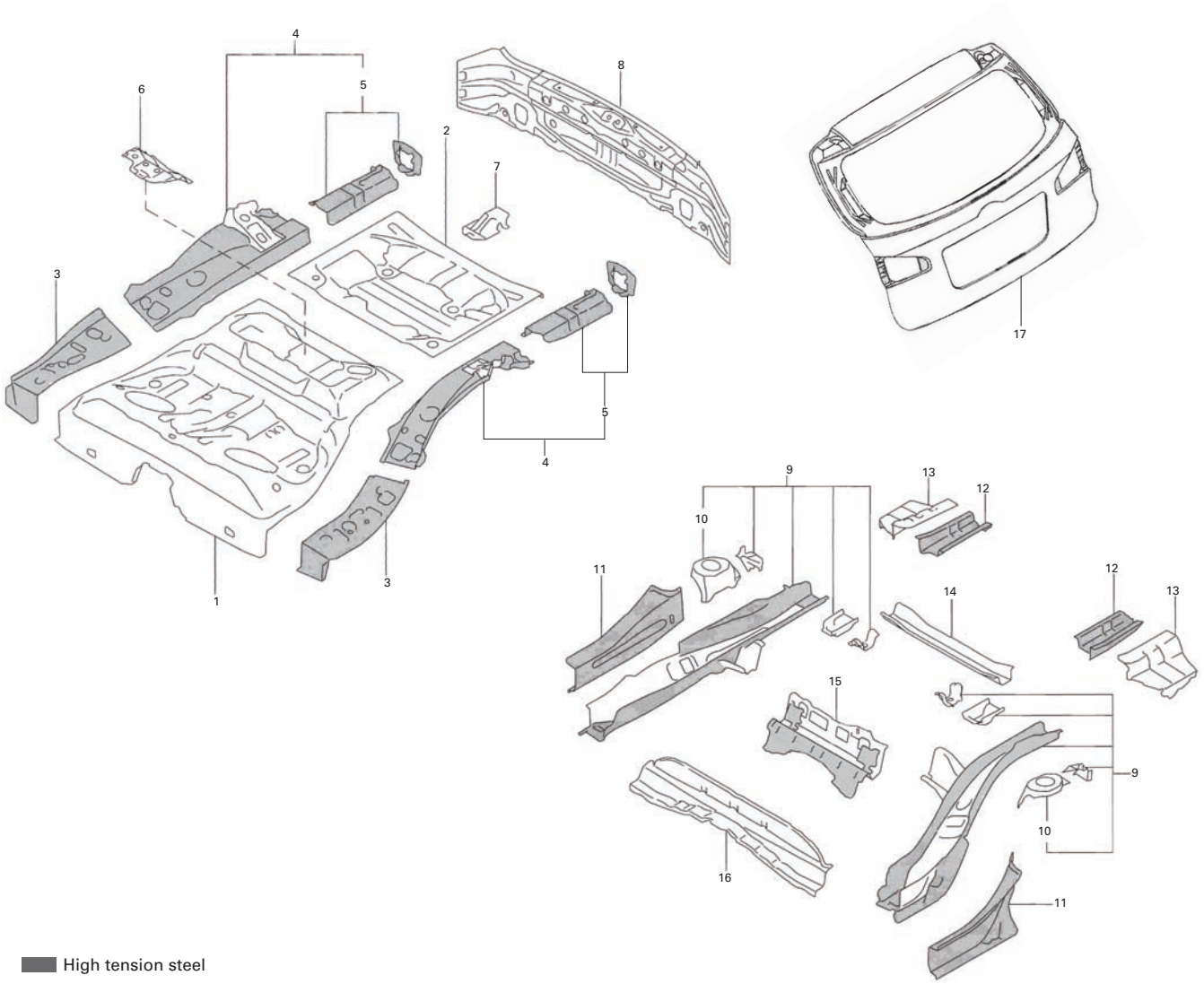
Because it is difficult to ensure strength in cabover wagons or vans, a member rather similar to a ladder frame is welded to the floor.

Somewhat different rear body structures are used for models with a separate trunk, hatchbacks and vans. Basically, there are quarter panels that incorporate the rear pillars at the side, a rear skirt at the back-end, a rear floor pan that serves as the floor to the trunk, and rear side frames welded to the other side of the floor pan. In models that have a trunk a panel separates the passenger compartment and the trunk.

Quarter panels are constructed with an inner and outer panel, and the inner side is joined to the rear arch which forms the wheel housing.

The rear floor pan is joined directly to the passenger compartment floor. The rear side frame on the other side is thinner and smaller than the front side frame. This is because it does not require the same strength as the front.

Rear body structure and parts



High tension steel

1. Rear floor front pan
2. Rear floor rear pan
3. Front side upper member
4. Rear side upper member
5. Rear of rear side upper member
6. Spare tire reinforcement
7. Spare tire bracket
8. Rear skirt
9. Front floor side member
10. Rear suspension bracket
11. Rear side sill inner
12. Rear floor side member
13. Rear floor side
14. Rear floor cross member C
15. Rear floor cross member B
16. Rear floor cross member A
17. Tail gate

* Refer to the diagram of the center body for a drawing of the side panels.

Chapter 3 Body materials

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1. Types of materials

Sheet metal is the main material used in body panels. A variety of elements are added to iron, and flat stretched sheets used as exterior panels are 0.6 – 0.8 mm thick and those used for pillars and frames (members) are 0.8 – 1.4 mm thick.

Corrosive resistant sheets are used for sites where rust prevention is important, and high tensile strength sheets are used for sites requiring high strength. Corrosive-resistant sheetmetal is normally zinc plated on both sides. Repairing corrosive-resistant sheets sometimes requires special treatment before applying putty or primer surfacer before painting.

Because high tensile strength sheets can have the same strength as standard sheetmetal even though they are thinner, they were initially adopted for large flat panels, such as the hood and doors, as a means of reducing weight. Today, however, they have a wide range of uses, including frames (members), pillars and reinforcements. Some exhibit slightly different properties compared with standard sheetmetal with respect to the way they deform when damaged and when they are repaired.

Aluminum alloys and plastic are two other materials used for vehicle bodies. Aluminum alloys with the same strength as sheetmetal is lighter, and so are used to reduce the weight of vehicles. Because the properties of aluminum alloys are different from steel, they require different handling for body repair, welding and painting.

Although plastic is mainly used for bumpers, the front grille, moldings, and interior components, plastic is also used for body panels. Repair methods vary depending on the type of plastic, and can require special tools and materials.

■ Body materials

Steel	Standard sheetmetal	Thin standard sheetmetal ranging in thickness from 0.6 mm to 0.8 mm are used depending on the section.
	high tension steel	high tension steel with the same thickness as standard sheets have higher strength.
	Corrosive-resistant sheetmetal	Sheets are made rust-resistant by zinc plating either one side or both sides.
Aluminum	Aluminum alloys used for body panels	Aluminum alloy panels that weigh approximately half as much as sheetmetal have the same strength.
Plastic	ABS	Acrylonitrile butadiene styrene
	BMC	Bulk molding compound
	PA	Polyimide = nylon
	PC	Polycarbonate
	PE	Polyethylene
	PP	Polypropylene
	PUR	Polyurethane
	PVC	Polyvinyl chloride
	SMC	Sheet molding compound
	FRP	Fiber-reinforced plastic = fiberglass-reinforced plastic
	Other types	

2. Properties of metal

(1) Common properties

Iron and aluminum used to form shapes are called metals.

Metals have the following common characteristics. They:

- Shine when polished (metallic gloss)
- Are solid at room temperature (mercury is an exception)
- Have a crystalline structure when solid
- Are opaque
- Are very hard
- Have high tensile strength
- Have plasticity
- Are forgeable
- Are resistant to fatigue
- Have a positive atomic value (on their own they have positive ions)
- Have good heat conductivity

Specific gravity: Metals have a high specific gravity

Melting point: Although they are solid at room temperature (excepting mercury), they expand and melt when heated. They turn into liquids. Melting point is the temperature at which this occurs.

Thermal conductivity: They conduct heat easily.

Conduction: They conduct electricity easily. Silver > Steel > Gold

Metal	Chemical symbol	Specific gravity	Melting point °C	Thermal conductivity 0°C Unit $W \cdot m^{-1} \cdot K^{-1}$	Electrical conduction 0°C Cu =100
Iron	Fe	7.86	1536	83.5	17.4
Aluminum	Al	2.70	660.37	236	62.0
Zinc	Zn	7.13	419.6	117	28.1
Copper	Cu	8.95	1084.5	403	100
Silver	Ag	10.49	961.93	428	103.4
Gold	Au	19.32	1064.43	319	76.0
Lead	Pb	11.36	327.5	36	8.1
Nickel	Ni	8.90	1455	94	24.8
Tin	Sn	7.30	231.9681	68	15.5

* Values differ slightly depending on the source.

(2) Mechanical properties

When metals are used for body materials their mechanical properties are checked.

1) Strength and hardness

Strong metals are those that have high resistance when pulled, compressed and bent. The surface of a hard metal is not damaged when load is localized. Steel is the strongest metal, lead is the weakest.

2) Ductility and malleability

Ductility is a metal's ability to be drawn or stretched, and malleability is a metal's ability to be shaped or bent. Together ductility and malleability are called forgeability. This is also called plasticity. Steel, aluminum, copper and nickel have this property.

3) Brittleness and toughness

A brittle material bends and breaks easily. A tough material is strong. Cast iron is brittle and steel is tough.

3. From iron to steel

Sheetmetal is made by rolling steel into thin sheets. Steel is made by melting iron ore, the raw material, and removing or adding elements after the iron is separated. Iron itself is hard to use as it is brittle when hard.
Steels with a variety of characteristics can be made by adjusting elements besides iron. Carbon is an important element, and the more carbon is added the harder the material. There are different categories of carbon steel depending on the amount of carbon added, such as soft steel and hard steel.
Other elements added to steel besides carbon (C) are silicon (Si), manganese (Mn), potassium (P), and sulfur (S). Although they are added in small quantities, they make a difference to the properties of steel. They generally increase strength, but steel can become brittle if large quantities are added.

■ Iron and steel

	Carbon content
Iron	to 0.035 %
Steel	0.035 – 1.7 %
Cast iron	From 1.7 %

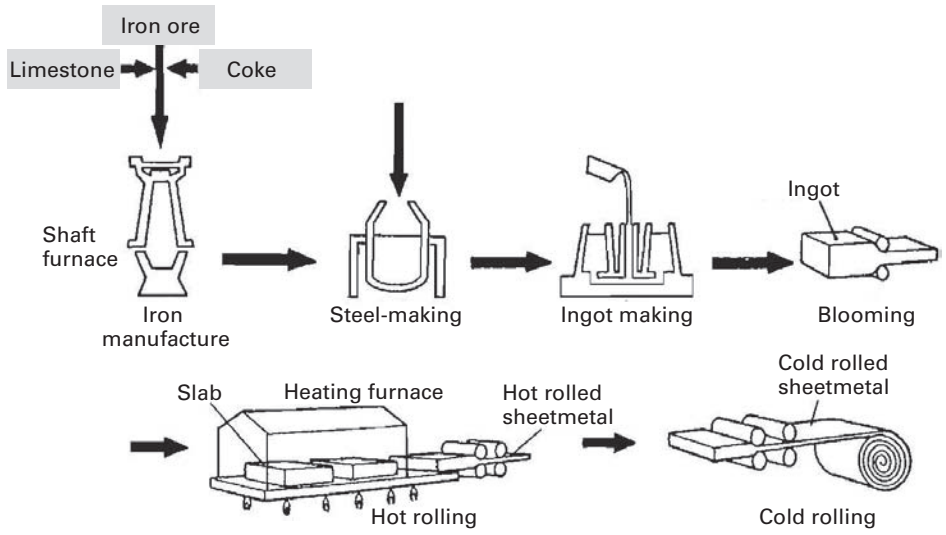
■ Types of steel

	Carbon content
Soft steel	0.12 – 0.20 %
Hard steel	0.50 – 0.80 %
Tool steel	Over 0.5 %
Low-carbon steel	Less than 0.3 %
High-carbon steel	OVer 0.6 %

(1) Sheetmetal manufacturing process

Steel is an alloy made by adding carbon to iron. It is easier to mass produce compared with other metal materials, is inexpensive, and steels with a variety of properties can be made by adjusting the content of other elements and by heat treatment. Steel that has been rolled into sheetmetal is highly formable and because it is inexpensive it is used in a wide variety of fields in addition to automobiles.
Sheetmetal is produced by the following process.

■ Sheet steel manufacturing process



1) Iron manufacture

Iron is removed from iron ore. Iron does not exist on its own, but is found in compounds, such as ferric hydroxide (red rust Fe_20_3) and triiron tetroxide (black rust Fe_30_4 = magnetic iron ore). Only iron is separated by removing the oxygen and others from iron ore which has a high iron content. Steel is produced by removing other impurities as well.

2) Steel-making

Raw iron has many impurities, and because it is hard and brittle it is not used very much. Steel with various properties is produced by removing impurities from the iron and adding necessary elements.

3) Ingot making/Blooming

Steel is cast by pouring melted steel into casts (ingot making) and rolling it into thick sheets (100 – 300 mm thick, blooming) while it is being heated. These sheets are called slabs.

4) Hot rolling

The slabs are heated, ferric oxide is removed from the surface, and the slab is rolled once into a thickness of 25 – 40 mm, the surface is cleaned once more and the steel is rolled into the required thickness. This is how hot rolled sheetmetal is made.

5) Acid cleaning

Ferric oxide is removed from the surface of hot-rolled sheetmetal by washing it off with acid.

6) Cold rolling

Cold rolled sheets are made by rolling steel to the required thickness at room temperature.

7) Annealing

The structure within the steel which changes during rolling is heated to between 650 ˚C and 700 ˚C to get rid of distortion.

8) Temper rolling

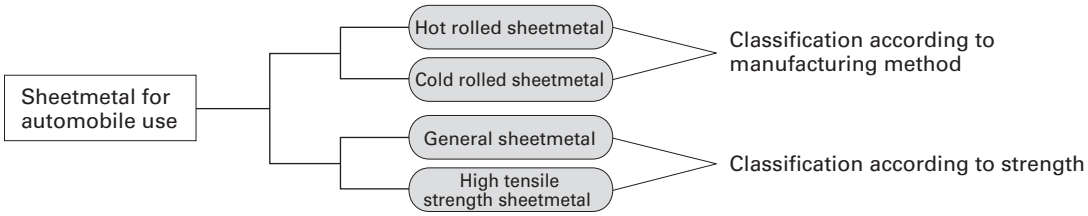
Surface finishing is done by lightly rolling the surface. This completes the steel sheet manufacturing process.

4. Types of sheetmetal

(1) Hot-rolled and cold-rolled sheetmetal

Sheetmetal rolled at temperatures between 800 – 900 ˚C is called hot-rolled sheetmetal. Hot-rolled sheets that are rolled once again into thinner sheets at room temperature is called cold-rolled sheetmetal. Most sheetmetal used in automobiles is cold-rolled. This is because compared with hot-rolled sheetmetal, ① it can be rolled to thinner thicknesses, ② it has a clean surface, ③ and has good workability.

■Types of sheetmetal



In the Japanese domestic market, sheetmetal is classified according to the following categories under Japan Industrial Standards. Please refer to the corresponding standards for each country as required.

1) Hot-rolled sheetmetal

JIS No.	Name	Code	Remarks
G3113	Hot-rolled sheetmetal for use in automobile structures	SHPH310/370/400/440	Sheet thickness 1.6 – 14 mm
G3134	Workable hot-rolled high tension steel for automobile use	SPFH490/540/590 SAPH540Y/590Y	For forming

* Figures denote tensile strength. 310 is a minimum strength of 310 MPa.

2) Cold-rolled sheetmetal

JIS No.	Name	Code	Remarks
G3141	Cold-rolled sheetmetal	SPCC, SPCD, SPCE	C is for ordinary use D is for drawing E is for deep drawing
G3135	Workable cold-rolled high tension steel for automobile use	SPFC340/370/SPFC390/440/490/540/590 SPFC490Y/540Y/590Y/780Y/980Y SPFC340H	For drawing and forming For forming Low yield ratio type Bake hardening type

* SPCD and SPCE have a minimum tensile strength of 270 MPa, and they are stretched 34 – 43 % depending on the thickness of the sheet. As a general rule, SPCC is not tested for tensile strength unless a request is made by the customer.

* The figures for high tension steel denote tensile strength. 340 is a minimum strength of 340 MPa.

(2) Corrosion resistant sheetmetal

When iron is left on its own, it combines with the oxygen in the air, forming rust (ferric oxide) on the surface. When it is left even longer, the rust gets into the inside, making it brittle. It is for this reason that sheetmetal resistant to rust is made by zinc plating the surface.

Different types from a wide range are used depending on the model and part of a vehicle. The main types are shown below.

1) Hot-dipped sheetmetal

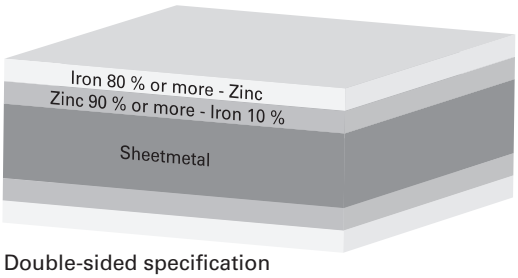
Sheetmetal is plated by dipping it in molten zinc. This is called hot-dipped sheetmetal. By immersing the sheetmetal in molten zinc, a zinc layer adheres to the surface.

Rather than a zinc layer on the surface that has high purity, dual layer alloyed zinc-plated sheetmetal that has two layers of a zinc and iron alloy is most commonly used. This is because it has superior weldability and paintability.

Making an alloy that contains iron by making an alloy layer that is 90 % zinc and 10 % and overlaying it with an alloy layer that is 80 % or more iron enhances paintability. Both paintability and corrosion resistance are provided by creating a zinc-plated layer containing a lot of iron and an inside with a lot of zinc.

Some corrosion-resistant sheetmetal is zinc-plated on one side only, while some is zinc-plated on both sides. When using sheetmetal plated on one side only, it is usual for the plated surface to be facing the inside of the body.

■ Dual layer alloyed hot-dipped zinc-plated sheetmetal



Double-sided specification

2) Corrosion resistance and handling

Sheetmetal is made corrosion-resistant by first covering it with a layer of zinc-plating, which prevents direct contact with the air, thus making it difficult for rust to form.

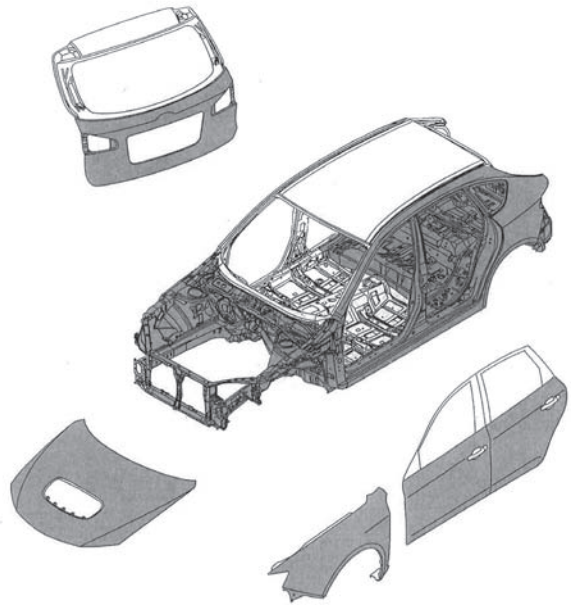
Next, if zinc and iron are present under the same conditions, the zinc will rust while the iron will not. Zinc rust does not penetrate as deeply as iron rust, and because it stops after forming a thin layer on the surface the rust will not penetrate the sheetmetal.

Zinc and paint have poor adhesion.

When the paint layer is removed by sanding when making repairs, the zinc-plated layer also comes off, exposing the surface of the sheetmetal. This renders the sheetmetal the same as untreated sheetmetal. But there are occasions when paint adhesion can deteriorate because the plated layer remains on feather-edged areas. However, paint used for repairs today is made to cope with zinc-plated sheetmetal so repair work can proceed as normal.

However, the removal of the zinc-plated layer means that a vehicle no longer has the corrosion resistance it had when new. Consequently, meticulous rustproofing should be done prior to painting.

■ Uses of zinc-plated sheetmetal



Sheetmetal on which both sides are zinc-plated

(3) High tension steel

Sheetmetal usually has a tensile strength of between 275 to 294 MPa (28 – 30 kg/mm^2). Sheetmetal that has a much higher tensile strength is called high tension steel. It has a tensile strength of between 390 to 490 MPa (approx. 40 – 50 kg/mm^2), or higher. High tension steel with a strength of 980 MPa (100 kg /mm^2) is not unusual. Sheets with a strength of 780 MPa or higher are called ultra-high tension steel.
High tension steel is made by adding minute quantities of other elements to standard sheetmetal. There are various types depending on the elements and production methods used.

1) Solid solution-strengthened sheetmetal

The sheetmetal is strengthened by adding carbon (C), silicon (Si), manganese (Mn), phosphorus (P), etc.

2) Precipitation-strengthened sheetmetal

Titanium (Ti), niobium (Nb), vanadium (V), molybdenum (Mo) etc are bound to carbon (C) and nitrogen (N), and added as minute elements to strengthen steel.

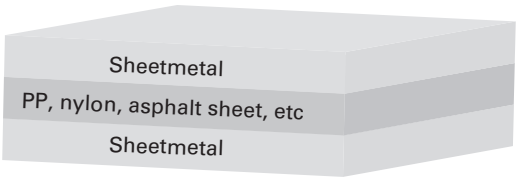
3) Compound structure sheetmetal

This is also called dual phase sheetmetal. The steel is strengthened by using heat treatment to alter the internal structure.

When temperatures of above 700 – 800 ˚C are applied to precipitation-strengthened and compound-structure sheetmetal, the internal structure alters and strength is reduced. It has to be heated to correct this deformation.
The adoption of high tensile sheetmetal has increased since around the time of the second oil crisis in 1979 as a means of improving fuel economy and reducing vehicle weight. Since it has high tensile strength and a high elastic limit, thin sheetmetal maintains the same strength as standard sheetmetal. Accordingly, when it is used for body panels it is thinner than standard sheetmetal.

(4) Vibration damping sheetmetal

Vibration damping sheetmetal is made by putting plastic between two sheets of sheetmetal. This type is also called a sandwich sheetmetal panel. It is used for the toeboard, etc because the middle plastic layer absorbs external vibrational energy. It also reduces noise.



5. Sheetmetal characteristics

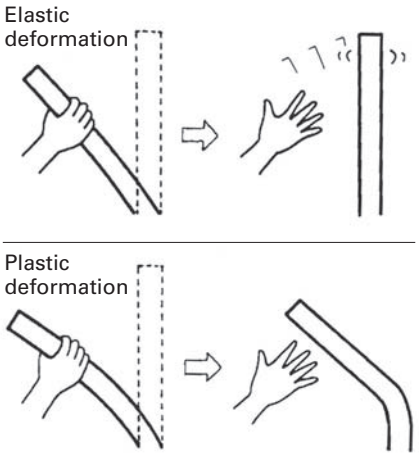
(1) Plasticity and elasticity

When sheetmetal deforms due to the loading of force, deformation occurs in two ways. There is deformation that is recoverable when the force is released and deformation that is not recoverable. The recoverable type is called elastic deformation and the unrecoverable type is called plastic deformation.

Only elastic deformation occurs when the force loaded to sheetmetal is weak. The amount of deformation increases in proportion to the amount of force that is loaded. Plastic deformation occurs when the force exceeds a certain level. When loaded force exceeds the elasticity of the sheetmetal, the degree of force at this point is known as the elastic limit. This is because creep occurs in the sheetmetal's internal structure.

When even more force is loaded, plastic deformation becomes greater and the internal structure of the sheetmetal fractures. The force at this point is the sheetmetal's tensile strength.

When force greater than the elastic deformation of sheetmetal is loaded, both plastic deformation and elastic deformation occur. When the externally loaded force is released, parts with elastic deformation return to their initial shape, while parts with plastic deformation will not return to their initial shape. When a panel is deformed in an accident, for example, plastic deformation and elastic deformation occur. Depending on the state of deformation, in many cases there is plastic deformation which constrains the recoverability of the elastic deformation. At such times, elastic deformation will naturally recover if the part with plastic deformation is repaired.

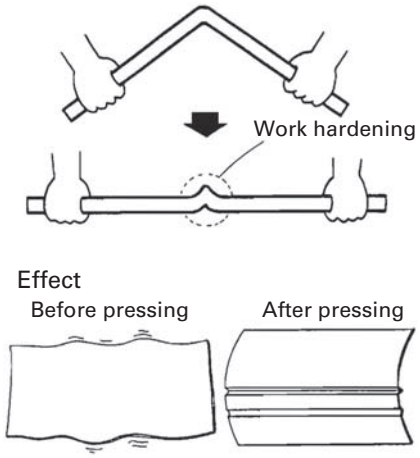


(2) Work hardening

When sheetmetal undergoes plastic deformation, it will become harder and its strength increases. This is known as work hardening. When body panels are made, the steel is work hardened using press forming. This is because exterior panels have an extremely thin thickness of 0.6 – 0.8 mm, and the required strength cannot be obtained without this process.

Work hardening also occurs in panels that have been deformed in an accident. Consequently, if force to recover its shape is loaded incorrectly, all that happens is that other parts will become deformed and the deformed parts will not recover their initial shape.

If heat above a certain temperature is applied to a work hardened area, the hardness created through the process will be eliminated and the area will return to its original elasticity. This is known as annealing. If areas that have work hardened and have become difficult to repair are heated with a torch they will become soft and will be easy to return to their original shape. However, the heat fractures the metal's internal structure, which will mean that the sheetmetal used in the body has considerably lower strength. Accordingly, as a basic rule members in underframe areas that ensure the body's strength and other welded panels must be repaired using annealing.



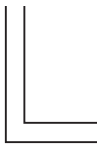
Even for a thin plate that easily undulate when applying force while it is left flat, if the press line is added, the line section will be work hardened and will have the same effect as inserting reinforcing members

(3) Work hardening of panels

Work hardening is used to increase the strength of panels. There are the following types of press lines that bend panels.

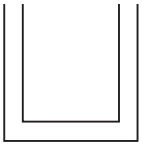
1) Flange

A flange is an edge that projects at a right-angle from a beam-like member where there is an angle bend. An example is the end of the front fender which has been bent at a right angle.



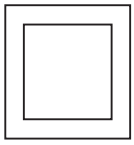
2) Channel

As the name suggests, this has a U shape, and is seen in processing of side frames.



3) Box

For underframe areas like side sills and pillars that require high strength, two U-channels are joined together to form a box.



4) Beading

Beading is the formation of a step in the middle of a panel to create a dent (or bump) to reinforce a flat panel such as the floor pan.

5) Hemming

The edge of an area where an outer and an inner panel are joined is pressed so that the outer side is tucked over the inner side. This method is used for the edges of doors and the hood.

6) Crown

Low crowns are often used in the roof, hood, and fender because of their design, but due to their low strength, they are combined with a high crown or a reverse crown in order to maintain strength.

The different types of crown are the reverse crown, the low crown (low curvature) and the high crown (high curvature).

(4) Tensile strength

Strength and rigidity have different meanings.

Strength is resistance to outside forces, such as pulling, compression and bending, in other words break-proof, and is largely used in connection with materials. Since it is the amount of force that can be withstood, it can be evaluated using figures from objective measurements.

In contrast, rigidity is an abstract term that refers to how something holds together. It is mainly used in connection with fabricated items. A material maintains the same strength no matter what kind of part it is, but its rigidity changes depending on the shape that is made and how it is combined.

One indicator of the strength of sheetmetal is tensile strength, which is mentioned in the previous chapter on types of sheetmetal. Tensile strength is measured by putting a thin long sample in a tester and pulling on both ends and seeing at what force the sample breaks.

The relationship between load (force) and the amount of deformation (pull) changes as shown in the graph.

Although when sheetmetal is pulled it stretches slightly in proportion to the force, from a certain point this will decrease and it will reach its elastic limit. When force is re-loaded, it will stretch to its upper yield point, stress will decrease, it will continue stretching irregularly until it reaches its lower yield point, when stress and pull will increase and it reaches its maximum stress point. This point is its maximum tensile strength. From this point only stretching will increase and it will break.

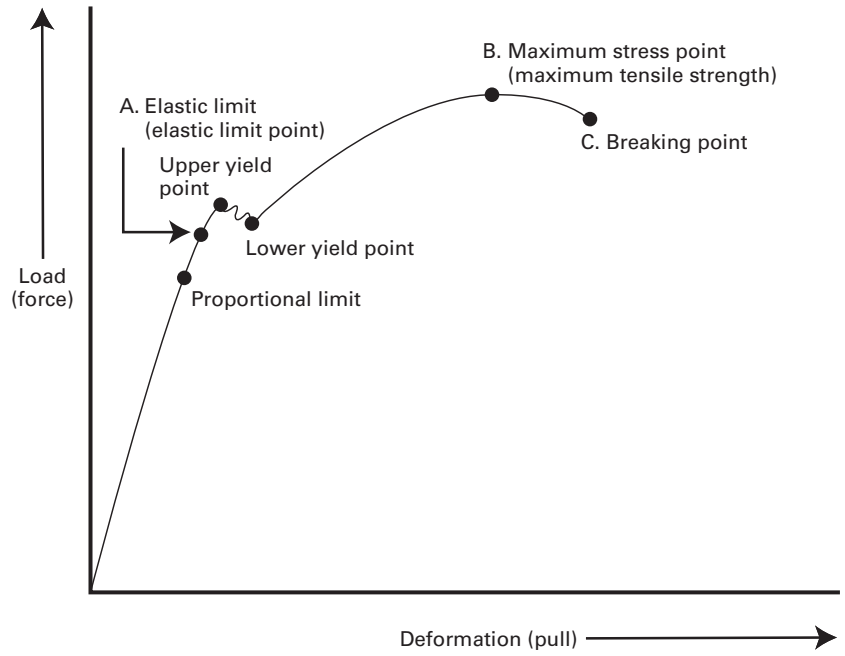
The figure showing tensile strength is calculated by dividing the maximum load N (B in the graph) by the cross-sectional area (mm^2) of the sample.

While elasticity, plasticity and work hardening are common sheetmetal properties, in this graph plastic deformation is reached when force exceeding the elastic limit is loaded. Even when the force is removed, the area that has deformed will not recover its original state.

Conversely, when force below the elastic limit is removed, the sheet will recover its original shape as soon as the force is removed.

The line shown in this graph applies to all sheetmetal. In the case of high tension steel, for example, the elastic limit will be at a much higher force so this whole line will move further up to the right in the graph.

■ Tensile strength and elastic limit



6. Aluminum alloys

(1) Types and characteristics

Aluminum is also used in auto body panels. Because aluminum weighs about a third of iron per cubic volume (specific gravity), it weighs approximately half that of iron with the same strength. It is also rust resistant and has good workability. It is used as an alloy which contains other metal elements. Because its properties such as thermal and electrical conductivity make it different to sheetmetal and it also has a different hardness, it is handled differently when used to make repairs.

Aluminum's appeal lies in it being the lightest material. It can be welded because of its thermal conductivity, which is around twice that of iron. It is used in auto body panels and mechanical parts, but it is expensive. Like iron it exists in the natural world combined with oxygen, because they are bound firmly the manufacturing process consumes a huge amount of electricity.

Because pure aluminum is soft other elements are added to make an alloy, heat-treated aluminum, magnesium and silicon alloys (6000 series) are the main alloys used in exterior body panels. Aluminum has excellent weldability and corrosion resistance. There is also non heat-treated aluminum and magnesium alloys (5000 series) which have excellent workability.

Aluminum is also rust-proof. With a melting point of 660 ˚C, it is lower than iron's melting point of 1,536 ˚C. But because its tensile strength lowers when it is heated, care is required. Even though it is light, its low tensile strength means that thicker panels are used.

It's a good idea to have an understanding of these characteristics when repairing aluminum alloy panels. Due to its low specific resistance, it is difficult to weld a stud with a conventional stud welder. The surface of aluminum is easily damaged and attention also needs to be taken with welding and painting.

■ Differences between iron and aluminum

Comparison with iron at 1	Aluminum	Remarks
Melting temperature	0.4	Melts without becoming red hot
Weight per same volume	0.34	Weighs approx. one third
Thermal conductivity	1.75	Has nearly twice the thermal conductivity
Electrical conductivity	1.9	Has nearly twice the electrical conductivity

7. Plastic

Parts made from plastic are used for a variety of parts, including the bumper face. It's necessary to know the properties of the plastic used for each site and to take them into account when making repairs. A special kit can be used when filling welds, patches and dents with putty. Do not use a hammer. It's more common for this to be done by those responsible for painting.

There are natural and synthetic plastics. Petrochemical synthetic plastics are used for automobiles. There are thermoplastic and heat curable synthetic plastics. These have different properties.

(1) Types and characteristics

1) Thermoplastic plastics

Thermoplastic plastics become soft when heated. They return to their original state when the temperature is lowered.

① Polypropylene (PP)

Has a light specific gravity and excellent strength, rigidity, thermal resistance, electrical properties, water repellency and chemical resistance.

Uses: Bumpers, headlamp housing

② Polyethylene (PE)

Has excellent transparency, chemical resistance and electrical properties. Has poor strength, rigidity and thermal resistance.

Uses: Mudguard, air flap

③ Polycarbonate (PC)

Has excellent impact resistance, thermal resistance and weather resistance. Has poor fatigue strength.

Uses: Headlamp lenses

④ Acrylic (PMMA)

It has high transparency, which is why it is used for paints. Also has good strength and workability. Is sensitive to impact or organic solvents.

Uses: Lamp lenses

⑤ ABS

Acrylonitrile butadiene styrene. Has good formability, but has poor thermal resistance and weather resistance.

Uses: Front grill

2) Heat curable plastics

When moulded and hardened at high temperatures, heat curable plastics will not soften if heat is applied.

① Polyurethane (PUR)

Has excellent elasticity, wear resistance and oil resistance, but is not very resistant to acids or alkalines.

Uses: Also used in paints and adhesive materials. Is used in foam form as a heat insulating and sound proofing material.

② Unsaturated polyester (UP)

Has excellent strength, rigidity and electrical properties. Has poor contractility and thermal resistance.

Uses: It is used in fiber-reinforced plastics.

③ Epoxy

Has good strength and electrical properties, but has no elasticity and yellows easily. It is also expensive.

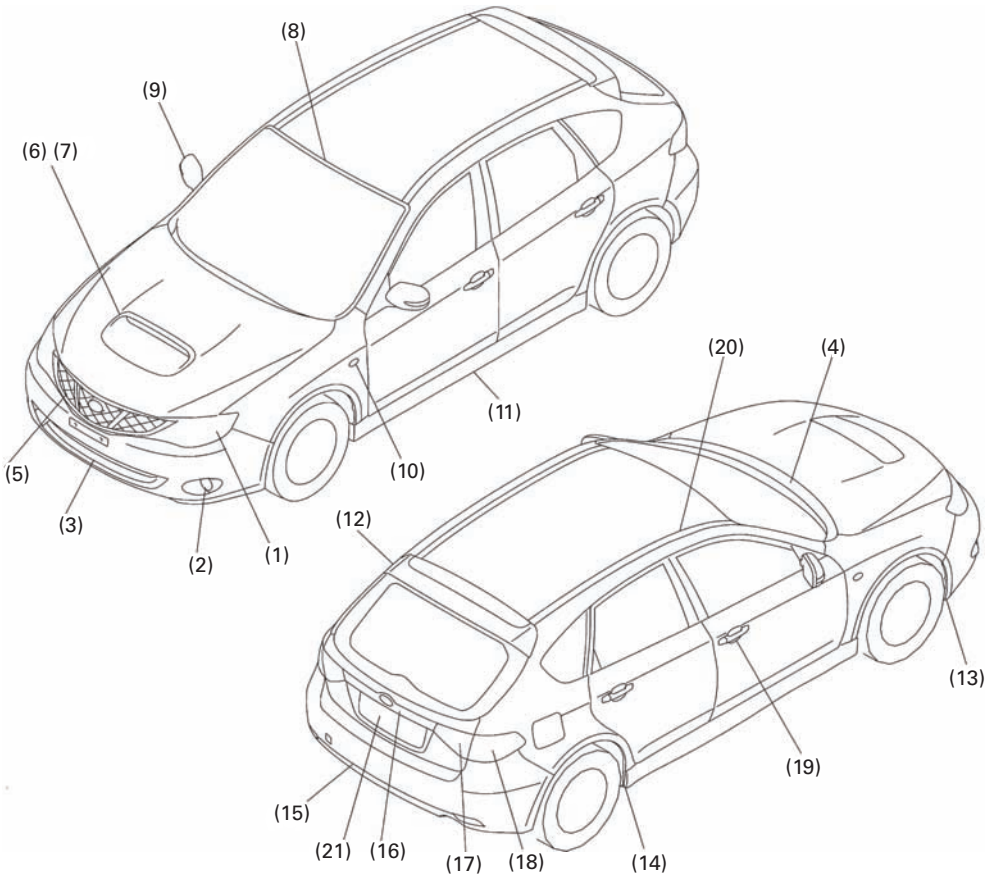
Uses: It is a high-grade plastic used in fiber-reinforced plastics.

④ Fiber-reinforced plastic (FRP)

FRP is made by impregnating unsaturated polyester with glass fibers to attain a high strength. The strength is increased if carbon fibers are used. (CFRP).

Uses: Body panels

(2) Plastic body parts and materials



■ Examples of plastic parts and materials

Number		Part name	Material
1	Headlamp	Lens	PC
		Housing	PP
		Extension	PBT+PET
2	Front fog lamps (standard)	Bracket (housing)	PP+GF40
3	Front bumper	Face	PP
		Fog lamp cover	PP
		Hook cover	PP
		Center lower bracket	PP
		Side bracket	POM
		Corner bracket	PP+GF30
4	Cowl	Body, side	PP
5	Front grille		ABS
6	Turbo grille		PA/PPE
7	Bonnet duct inner		PP+EPDM
8	Front window molding		PVC
9	Door mirror	Body	ASA
		Inner cover	AES
		Outer cover	ABS
		Mirror housing	PP
10	Side indicator lamp	Lens	PMMA
		Housing	PC
11	Side spoiler		PP
12	Rear spoiler	Body	ABS
		High mounted lens	PMMA
		High mounted housing	ABS

13	Front mudguard	Body		PE
		Air flap		PE
14	Back of air flap			PE
15	Rear bumper	Face		PP
16	Rear gate garnish			ABS
17	Backup lamp	Lens		PMMA
		Housing		ASA
18	Rear combination lamp	Lens		PMMA
		Housing		ASA
		Reflector		PC
		Reflex reflector		PMMA
19	Door handle	Standard model	Handle	PC+PBT
		Smart opener model	Handle body	PC+PBT
			Antenna cover	PC+PET
		End cover		PC+PBT
20	Roof molding			PVC
21	Rear gate opener switch			PP+GF35
	Under cover	Body		PP
	Splashboard			PP
	Rear wiper	Blade		PBT
		Arm		PET
		Arm cover		PBT

■ List of plastic reference symbols

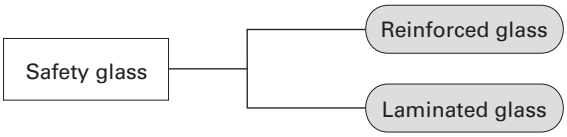
Reference symbol	Name of material	Resistance to solvents	Heatproof temperature
ABS	Acrylonitrile butadiene styrene	×	80
AES	Acrylonitrile ethylene styrene	×	80
ASA	Acrylonitrile acrylate	×	80
EPDM	Ethylene propylene diene monomer rubber	×	80
PA/PPE	Polyamide/polyphenylene ether	△	80 to 100
PBT	Polybutylene terephthalate	○	160
PC	Polycarbonate	×	120
PE	Polyethylene	○	80
PET	Polyethylene terephthalate	×	180
PMMA	Polymethyl metacrylate	×	80
POM	Polyacetal	×	120
PP	Polypropylene	○	80
PP-GF20	Polypropylene (containing 20% of the glass fiber)	○	–
PP-GF30	Polypropylene (containing 30% of the glass fiber)	○	–
PP-GF40	Polypropylene (containing 40% of the glass fiber)	○	–
PVC	Polyvinyl chloride	△	80
TPO	Thermoplastic olefin	△	80
UP	Unsaturated polyester	×	90

8. Glass

Various types of glass are used for the front windshield, rear window and doors of automobiles.
Standard glass has had silicon (Si), soda (NaO_2) found in ash and caustic lime (CaO) added to it. Colorless and transparent, it is also resistant to acids and alkalines.
Using a safety glass in automobiles is obligated. Safety glass must not cause injury if broken and must enable a certain field of view.

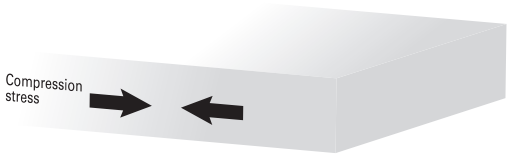
(1) Safety glass

There are two types of safety glass. There is reinforced glass with increased strength and laminated glass designed to lower danger when it breaks.



1) Reinforced glass

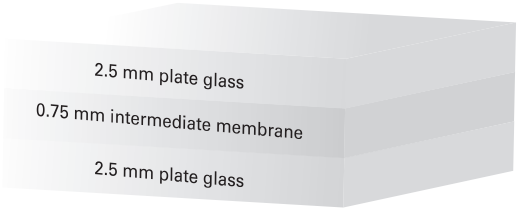
Reinforced glass is used in doors and for the rear window. It is made by heating sheet glass to around 600 ˚C and then cooling it rapidly. Glass breaks due to tension upon impact. But because with reinforced glass high compression force is locked inside it is extremely hard to break. It has between three to five times the impact resistance of ordinary glass. It can also withstand huge differences in temperature.
If it does break, it breaks into many round fragments.
There is also reinforced glass that will maintain a certain field of vision even when broken.



Compression stress against the impact is sealed in

2) Laminated glass

The use of laminated glass for windshields has been mandatory since 1987. Laminated glass has a thin robust plastic membrane sandwiched between two sheets of glass. When broken it does not fragment but stays in one piece, allowing visibility. It also makes it difficult for objects to penetrate the windshield.
Laminated glass with a thick layer in the middle with high impact resistance is called HRP laminated glass.



The intermediate membrane made of polyvinyl butyrate is sandwiched between two sheets of glass

(2) Special glass

It is common for additional functions to be added to glass used in automobiles.

There is laminated glass that has antenna wire integrated in the middle layer, tinted glass where a tint has been added at the top of the middle layer, tungsten heating wires embedded in middle layer to prevent fogging and mist, and glass that stops ultraviolet rays.

Types of reinforced glass include heat-absorbing glass that absorbs infrared rays which is made by added minute quantities of metal elements, glass that absorbs and blocks ultraviolet rays, heat-reflecting glass, heat ray printed glass printed with an electrically conductive paint, and tinted glass to lower transparency and improve privacy.

(3) How to distinguish different kinds of glass

At the bottom of automotive glass there is the JIS mark as well as the name of the glass manufacturer and symbol denoting the type of glass.

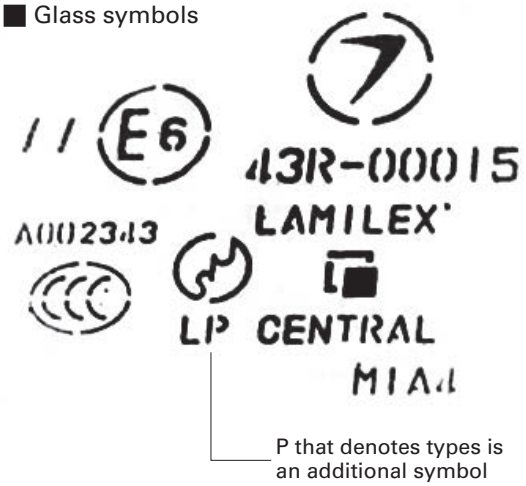
You can distinguish different types of glass from the symbols found below the JIS mark.

L → Laminated glass

T → Reinforced glass

Z → Partially reinforced glass

■ Glass symbols



Chapter 4 Repair procedures

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1. Order of tasks

Damage caused in an accident varies and damage will always be different even in the same kind of accident. However, there is a standard order in which to make repairs which can be followed for all types of vehicle damage.

Repair work is broadly divided into panel beating and painting.

(1) Panel beating

Panel beating is the task of using various tools and machines to restore deformed panels, the body and members to near original condition. It involves replacing panels that cannot be restored or which will require too much time as well as replacing damaged suspension, engine and other parts with new ones.

In the narrow sense of the term, panel beating refers to the repair of panels only.

(2) Painting

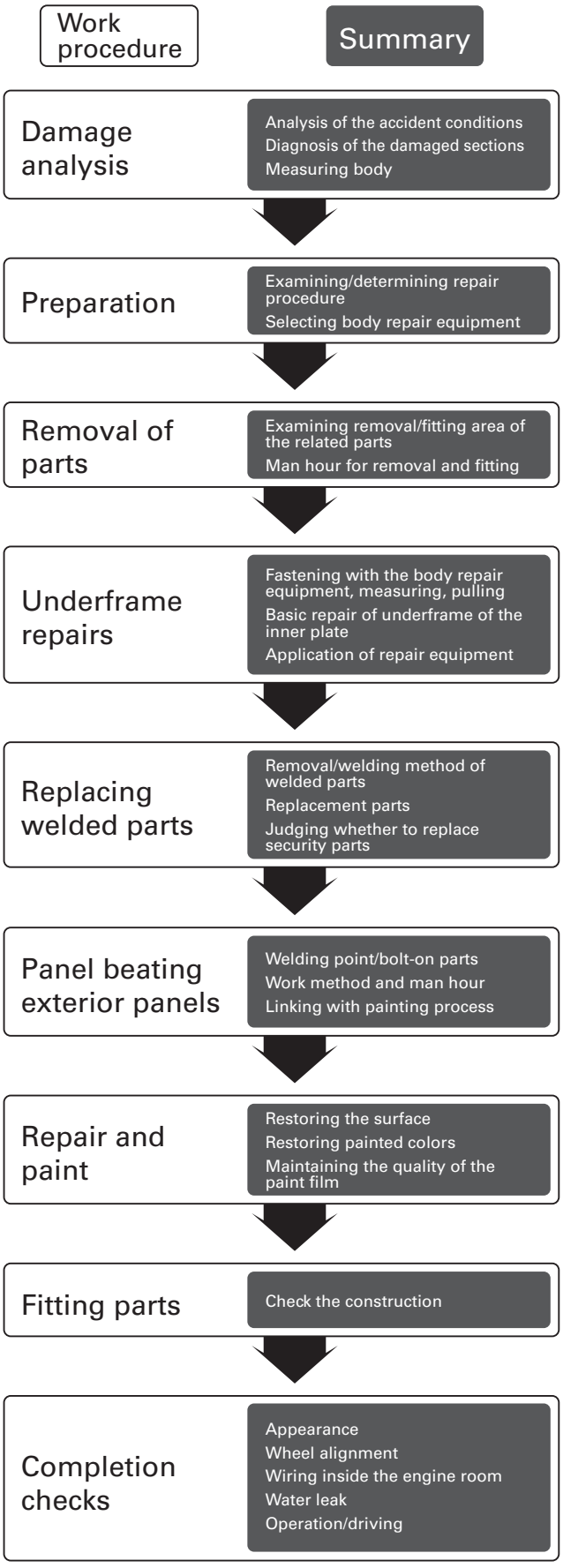
Painting is the task of painting restored panels and new parts so that they look like new. When panel beating has been completed the quality can vary depending on the skills of the worker and methods used, but they never really return to their pre-damage state. Some surface scratches are also left by panel beating. In such cases, a primer coat is applied to the substrate to prepare the surface for spray painting with a top coat the same as the body color.

(3) The line between panel beating and painting

The line between panel beating and painting differs from workshop to workshop. In cases where machines and tools are used to repair panels only, a panel beater does the work up to the point just before the painting of the top coat. In some cases the line is drawn before the painting of the primer coat.

In general, it is common for a panel beater to be in charge of work up through the sanding of body filler to create a smooth surface.

In some cases the work is divided into the three tasks of panel beating, painting and the substrate, and in some cases no distinction is made between panel beating and painting. In such cases the aim is to acquire skills so that the same person is able to work on every stage.



2. Damage analysis

Analyze the circumstances surrounding the cause of the damage before deciding on the order of repair tasks.

- Where there has been an accident, this includes the shape and rigidity of the object the vehicle crashed into, relative speed, angle, etc.
- Impact entry site and direction

This information is used for considering the extent of the damage and the direction in which to pull out the damaged part.

Measure the extent of the damage and amount of deformation.

3. Preparation

Draw up a plan based on damage analysis information.

1) Decide the order of tasks

The general method is to repair the underbody and work upwards to the upper body.

Where a car is damaged in a longitudinal direction up to the passenger compartment, the general rule is to take precise measurements starting with the passenger compartment and working out to the front, or the rear.

2) Decide whether to repair or replace

The decision on whether to repair or replace varies depending on the type of panel to be repaired, role, extent of damage, repair site, technology, and workshop policy. Although a decision taking all factors into account is required, opt for repair if the cost of repairs falls under 70% of the cost of replacement.

3) Select repair equipment

Once you have made basic decisions such as confirming the extent of the damage and deciding whether to repair or replace the damaged section, you will need to select the equipment to use for the repairs. Equipment ranges from simple through to embedded systems. There are three fixed methods that use floor, platform and jig systems, and setting and resetting time also varies. An effective way to repair small and medium size damage is to use a floor system that is easy to set.

4) Gather and check model information on body structure, etc

Gather information about precautions concerning repair sites by getting materials such as body repair manuals.

4. Removal of parts

First wash the car to remove dirt and dust and then start repairs from the step required according to the extent of the damage.

Remove damaged parts that are bolted on, parts that need to be removed in order to repair or remove damaged parts, and interior parts that will affect the repair work.

It is common to remove welded parts at a later stage while making repairs to the underframe.

5. Frame repairs

Set up body repair equipment. Also measure the dimensions of each site while referring to drawings of body dimensions and check the extent of the damage. Using your measurements, pull out the necessary amount of the damaged site and restore it to its original dimensions. Even if there are welded panels that need replacing, leave them and carry on with repairing the car body. This body repair work is known as body alignment.

6. Replacing welded parts

When each part has been restored to its original dimensions, cut out the welded parts that are to be replaced. Remove by cutting along the original weld lines.

Tack new panels to the body and make tiny adjustments to the body by pulling using repair equipment. Also attach external parts and check the gaps between the panels. Weld the replacement parts when they fit neatly to the body. This completes repair work done using body repair equipment.

7. Panel beating exterior panels

Damaged panels that are not replaced are repaired by removing surface paint and then using methods such as beating with a hammer or pulling using welded washers or studs (pins). Depending on the site and extent of the damage, bolt-on parts may be removed and then repaired.

8. Painting

The painting process consists of two main parts: the primer coat and top coat.

Tools used and the order of work for the primer process which follows body and panel repair differs from workshop to workshop. Basically there are two processes. One is applying putty to fill in deep damage and the other is to fix tiny dents on the surface and use primer surfacer so that the top coat will adhere well. Sometimes the extent of the damage requires the putty work stage to be done in two stages. Small dents on the primer surfacer can be repaired using finishing putty.

Painting the top coat is an important process as it affects appearance after repairs have been made. The quality of painting is greatly affected by the entire paint film (painting system), including the primer coat.

9. Attaching parts

Bolted on parts removed at the beginning are refitted when all stages are completed. Moldings and decals are attached at this stage.

10. Completion checks

Check the appearance of the car and the wiring inside the engine room. Check wheel alignment and whether the various parts are functioning normally. If there are no problems, arrange for the car to be delivered to the owner after cleaning the interior and washing the car.

Chapter 5 External panel repair

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1. Scope of deformation

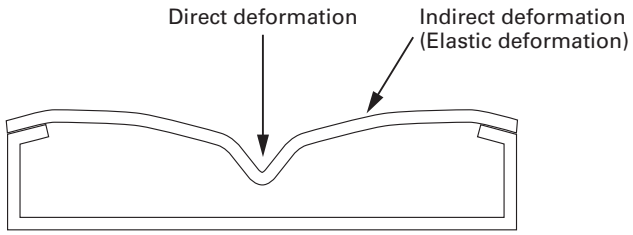
(1) Types of deformation

Body panels deform when they receive an impact. Dents are caused, but they are not the only sites where deformation occurs. There are cases where deformation occurs at sites away from the point of impact entry. This depends on the direction of the impact, site, and degree of force.

This type of deformation is called indirect deformation or secondary deformation. Deformation caused at sites that received direct impact is called direct deformation or primary deformation.

It is common for indirect elastic deformation caused as a result of an impact to occur at sites that are fixed to the damaged point of impact. Consequently, this deformation will naturally return to its original shape when the main deformation is restored. Inadvertently restoring the damage starting with the indirect deformation will make restoration more difficult as it could require stretching panels. To do the work efficiently in a short period of time it is important to follow the correct order based on an accurate assessment of the type and state of the damage.

■Types of deformation



(2) Washing and cleaning

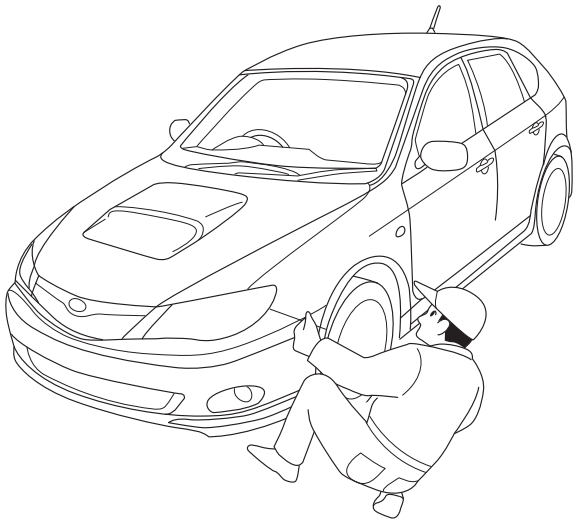
It is vital to wash the vehicle before starting work. Wash the entire body. Pay particular attention to the damaged site and surrounding area. It is hard to see the damaged site or determine the state of the damage if there is dirt or mud on the vehicle. For this reason, clean the car by washing not only the body surface but also the other side of the panels with water and remove any grease using a detergent. Wash the car starting at the top and work down.

(3) Checking for dents and bumps

1) Visual check

If the paint film is not damaged, make a visual check for any deformations by shining a light on the body surface. They're easy to see if you leave some space between you and the site you're checking. If there is not much light, wetting the site with water is useful.

Sometimes they're easier to see if you change your position or angle and make a comparison. If right and left have the same shape use the non-damaged side for reference.



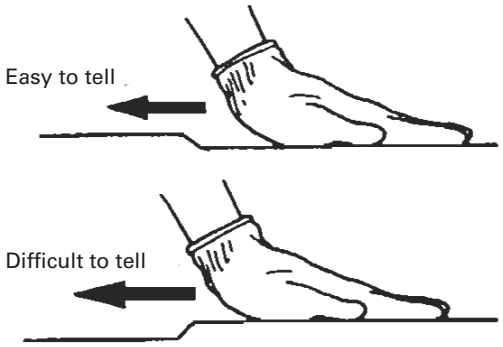
2) Hand check

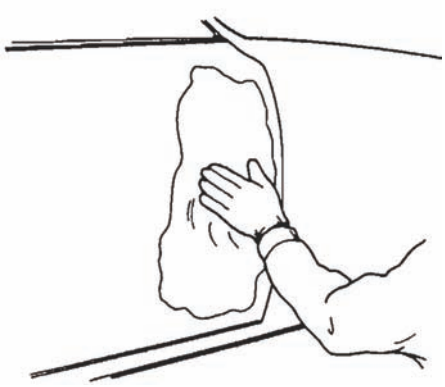
When the deformation is tiny or you're nearing the finishing stage it can be extremely difficult to tell what has been restored to its original shape and what hasn't.

With experience, you will be able to perceive tiny dents by running the palm of your hand or fingers over an area. Standard practice is to do this with your non-dominant hand and to wear a thick cotton glove. The skin on your dominant is thicker. Also, put a glove on it as well so you can't feel the temperature of the panel surface.

Run the palm of your hand from the probable deformation site outwards. Deformation is easier to detect if you draw your hand away rather than drive it in. This is because detection is easier if you start low and move higher rather than starting high and moving lower.

Feeling with fingertips



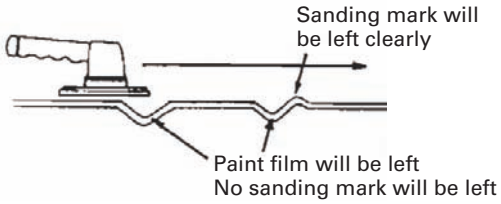


Check with your non-dominant hand

3) Sand using a sander

If you use a disc sander or special paint removal sander to lightly sand the deformation site the paint will remain in low spots and most of it will come off in raised spots. Even after the paint has been removed, the size of the sanded area left on the metal section of the panel will make it easy to see which parts are raised and which are low. However, if you leave deep sanding marks it will take time to fix it up later on. Therefore, sand as lightly as possible using uniform force across the entire area.

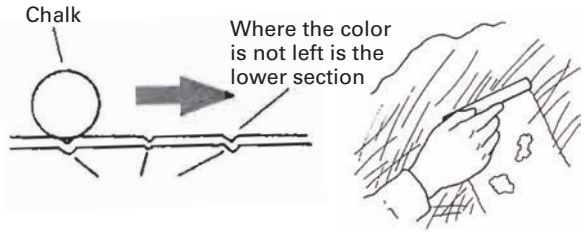
You can also use a file instead of a sander. If you file lightly with medium grained file, filings won't adhere to low spots.



4) Use chalk

Take chalk used to write on the blackboard, hold it sideways and run it over the body. Normal parts will color up while the color of the chalk won't stick to dents.

There are other tools like straight-edges.



(4) Distinguishing elastic deformation and plastic deformation

When a panel receives an impact, the deformation that occurs is either elastic or plastic deformation. Although normally when the force is unloaded (after the impact), parts where elastic deformation has occurred will return to their original shape. However, plastic deformation which stops this from happening often occurs as well.

A good panel repair method is to use force that restores elastic deformation. In other words, do not work on parts with elastic deformation and instead repair only parts where plastic deformation has occurred. If you do that parts, then elastic deformation will automatically return to their original shape.

Accordingly, being able to distinguish between elastic deformation and plastic deformation is a requirement for carrying out panel repairs efficiently.

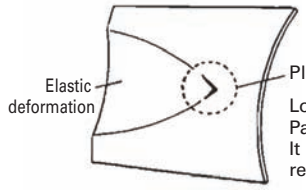
The edge of elastic deformation is not obvious in a visual check, as panels deform on a relatively gentle incline. Also, if dents are pushed from the rear, the deformation changes shape while moving the top of the panel.

In contrast, when there is plastic deformation you're most likely to find sharp angles and peeled paint. When you push a dent from the rear, the deformed area will stay still while the surrounding panel surface will move.

■ Deformation patterns and repair points

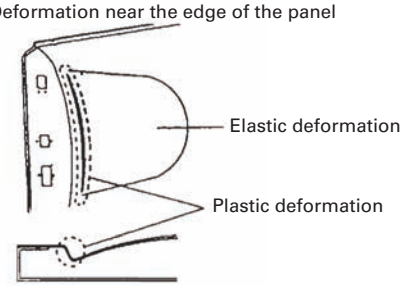
Wide mild deformation

● Deformation at the center of the panel

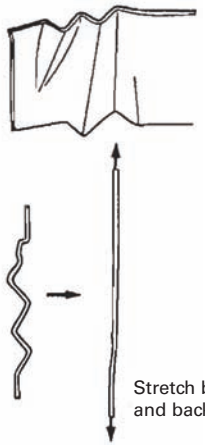


Looks like being bent
Paint is peeled
It is easier to restore by repairing only this part

● Deformation near the edge of the panel



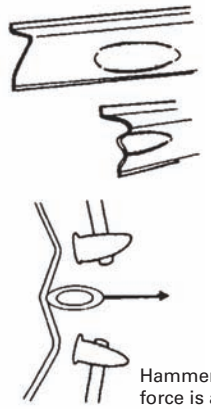
Deformation in the form of creases



Stretch by pulling from front and back before repairing

Long narrow deformation

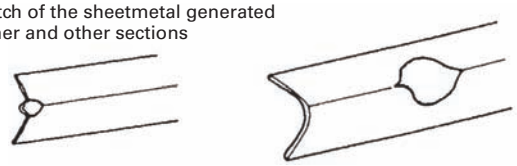
In most cases, top and bottom are plastic deformation while left and right are elastic deformation

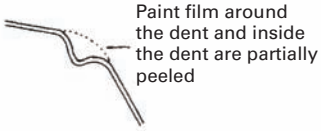


Hammer while force is applied

Narrow sharp deformation

Large stretch of the sheetmetal generated at the corner and other sections





Paint film around the dent and inside the dent are partially peeled

If pulled incorrectly, surrounding area will be lifted

(5) Panel beating methods for different repair sites

Hydraulic equipment is used when strong force is required for pulling, though most repairs to outer panels are done manually.

Hammering, or tapping, is when a panel is placed against a dolly or body spoon and the deformation is repaired by beating with a hammer. This requires you to be able to reach your hand round to the back or to insert a tool instead.

In contrast, pulling is when a slide hammer (dent puller) or stud pin washer welder (sometimes this is simply called a stud) is used to repair the panel by pulling it out.

There are different types of pulling. There is vacuum pulling where suction is used, pulling that uses clamps, pulling that uses a slide hammer with replaceable head attachments for different sites, weld pulling that uses plastic tools as well as studs.

Small dents are also massaged by inserting a tool in the gap and massaging the dent from the rear.

Choose the most appropriate method depending on the site of the panel damage, and where necessary use a combination of methods.

■ Panel beating methods

1) Ends of panels with openings: Wheel arch

Deformations at the ends of panels like the wheel arch which has an opening can be pulled by attaching a hook-type attachment to a slide hammer. Of course, this can also be done by normal washer pulling, and because you can reach your hand in behind you can also beat the deformation.

2) Repairs that can be made from behind: rear quarter panels, etc.

At some sites like quarter panels, the hood and trunk lid, if you remove the trim you can reach your hand or a tool around to the other side. Consequently, in addition to pulling you can also do planishing where you hammer out the deformation.

3) Repairs that can only be done from the rear

Pulling is done when you can't do the work from the rear without removing the part, such as for welded parts like side sills, doors and the middle of fender.

However, since it is easy to remove the front fender you can remove it to panel beat it by hammering.

2. Hammering and pulling

Pulling has the following advantages over hammering.

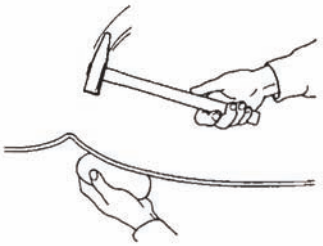
a. Because pulling is done from the outside, the work can be done regardless of whether the other side is a pouch structure or whether there's an obstacle in the way. There is no need to cut the rear side or remove and replace parts more than is necessary.

b. Hammer blows stretch sheetmetal. There is relatively little stretching when pulling. You can also get away with doing a minimum of shrinking.

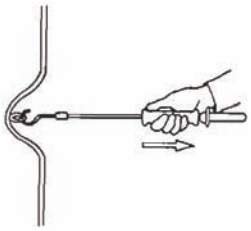
c. Work is fast because a large amount of force can be applied if necessary.

d. By using a variety of tools and attachments you can acquire the necessary skills in a relatively short period of time.

■ Hammering



■ Pulling



3. Massaging

Although hammering and pulling are the two main methods of panel beating, there is also massaging. Dents are repaired by pushing them out from the rear side of the panel. This is used for small dimples like those caused by hail. Special kits of dent tools are used for this process.

A thin long rod-like dent tool is put under the dent, and the dent is massaged from the rear using the rear panel as a fulcrum. This makes it possible to repair the dent without damaging the top paint.

Since the tools are inserted into the back of the panels, use the tool with the correct shape for the particular site.

There is a variety of other tools, including special light sources for looking at dents, and magnets attached on the front side to make it easy to find the exact spot.

■ Dent repair tools

4. Pulling points, lines and planes

Simple damage caused by a single entry point can be repaired by pulling with the appropriate amount of force. In reality, however, such simple damage rarely exists.

In principle, it is easier to pull a line than a point, and pulling a plane is even easier.

When pulling a point, depending on how much strength you use, you can pull too hard on just the point at the center. If hammering of the surrounding area is neglected the deformation can become more complicated. There is, therefore, a tool that is used like a lever so that by pushing down on the surrounding area the center is pulled with a pinpoint.

For damage that runs along a line, there are also tools that will pull an entire long line. For planes there are pulling methods where a plate is attached using a special solder.

5. Body repair tools, equipment and materials

(1) Hammers

1) Role of the hammer

The hammer is a tool that has come to symbolize body repair. However, in body shops today apart from the restoration of classic cars you won't find repairers using hammers and dollies to beat panels of every conceivable shape to restore them to their original contour as was the case some years ago. The reasons include ① advanced technology is required; ② it takes time; and ③ the price of parts is relatively inexpensive and they're also easy to obtain.

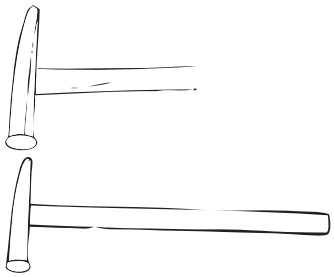
2) Hammers and related tools

The term hammering is used for various tasks performed using a hammer. There are a number of other tools required for hammering and there are also different types of hammers. The main types of hammers are listed below.

① Bumping hammer

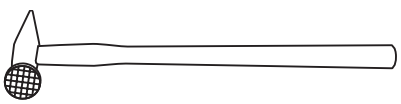
The bumping hammer is indispensable for repairing panels. At one end the face is a round flat striking surface while face at the other end is thinner and slightly curved. The precision of the striking surface is different from hammers used to hit nails. Do not use these because they could leave a dent.

Although of a similar shape, those that are bigger are used for roughing out.



② Shrinking hammer

The striking surface is cross-milled like a file, and when shrinking stretched sheetmetal the hammer is used in combination with a dolly with a similar type of surface.

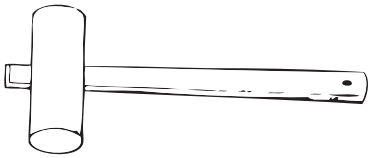


③ Pick hammer

A hammer with a thin sharp point. Used for repairing very small protrusions and dents.

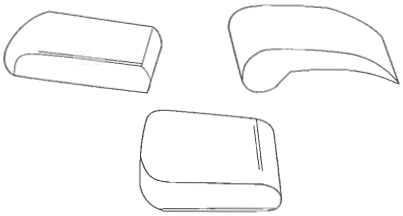
④ Mallet

A mallet is used to apply light force when you don't want to remove paint or stretch the panel. The head is made of wood. Hammers with a plastic head can be used for the same work.
In some cases you can get the same result by placing a small piece of wood against the panel and beating a standard hammer against it.



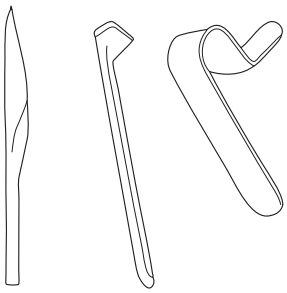
⑤ Dolly

A dolly is a block of metal that fits in the hand. A dolly is used to hold the surface being hammered or a nearby site. A dolly can be used instead of a hammer for places where a hammer can't reach. Choose a dolly with a shape most suitable for the repair site.

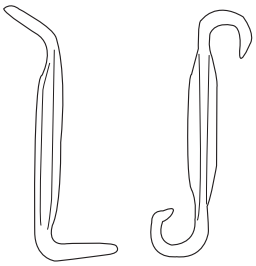


⑥ Spoon, lever

A steel rod where either one or both ends have been shaped like a thin spoon. A spoon can be used instead of a dolly to reach places hard to reach with your hand. It can be used like a lever when making panel repairs. They come in a variety of shapes and lengths for different sites.
A lever has an S shape and has sharper angles than a spoon, and has bent tips.



Spoon



Lever

⑦ Chisel

Although a chisel is usually used for cutting panels and removing welds, chisels are used for beating press lines because of its wide semi-cylindrical blade.
When chisels such as cold chisels are used the end is hit with a hammer. In such cases a bumping hammer must not be used.

Cold chisels

⑧ Center punch

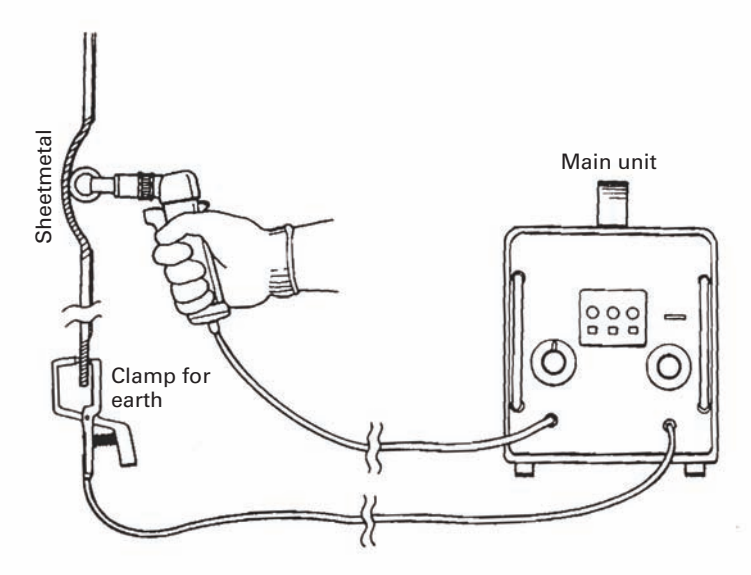
A center punch is normally used to make a dent in the center so that the drill blade does not slip when making a hole. In panel beating it can also be used to hold down a high point. Unlike a pick hammer, the repair site can be lowered without the center punch slipping off the repair site.

(2) Stud welder

Called a stud pin washer welder in full, the name is often shortened to stud or stud weld.

When this method of pulling was first developed, a thin rod, that is, a stud pin, was used to gain leverage. Today, washers or shaped washers are commonly used.

The principle is the same as that for a spot welder. A weld is made with the resistant heat generated when a strong current is discharged through a narrow area.Consequently, there are spot welders that can perform this function. Although stud welders are commonly used because they are compact, lightweight and simple, since a stud welder does not have the power of a spot welder it cannot make proper welds.



(3) Pulling tools

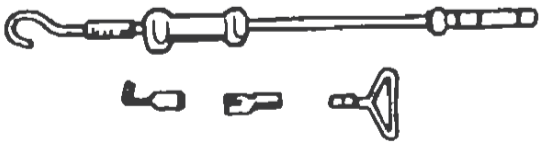
1) Slide hammer

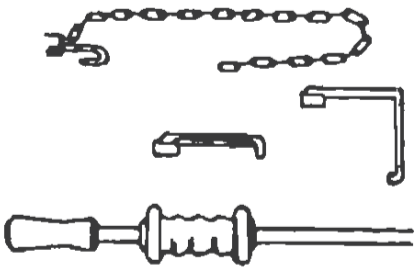
Studs and slide hammers (dent pullers) are typical tools used for pulling. Force is applied by the reverse action when the weight in the middle is moved.

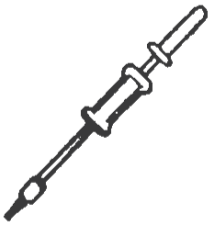
Slide hammers come in a variety of lengths and with a variety of weights. Select a slide hammer according to the site and extent of the damage.

Since the head is replaceable, you can choose the appropriate attachment for the job, such as a hook to pull washers and stud attachments and hooks that hook on to the end of panels.

If you use a stud puller with an electrode you won't need a slide hammer and stud, but it can only be used to pull out one site.

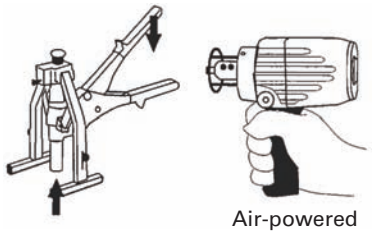






2) Lever-type pulling rod

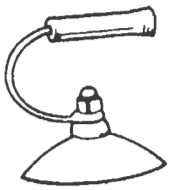
Clamp a stud pin or washer in the center, brace both sides or the top of the circle and pull the lever. The metal is pulled out using the principle of a lever. Because it makes it possible to use a point to pull out only the corresponding surrounding surface it is a good method for beginners. There are also air-powered pulling rods.



Hand-held type Air-powered type

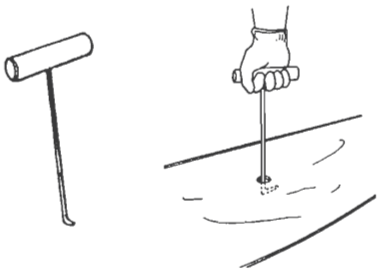
3) Suction puller

A suction puller works by attaching a suction cup to the sheet metal. When there is elastic deformation in doors and outer panels, a suction puller can be used to pull out and restore the shape of the surface quickly, providing the pull point is appropriate.



4) Hooks

Force can be applied to a panel using just the hand by hooking a hand hook into a washer or a hole in the panel. Hand hooks are useful for repairing relatively light damage by hammering an area with plastic deformation while pulling an area with elastic deformation.



(4) Tower, chain puller, hydraulic ram

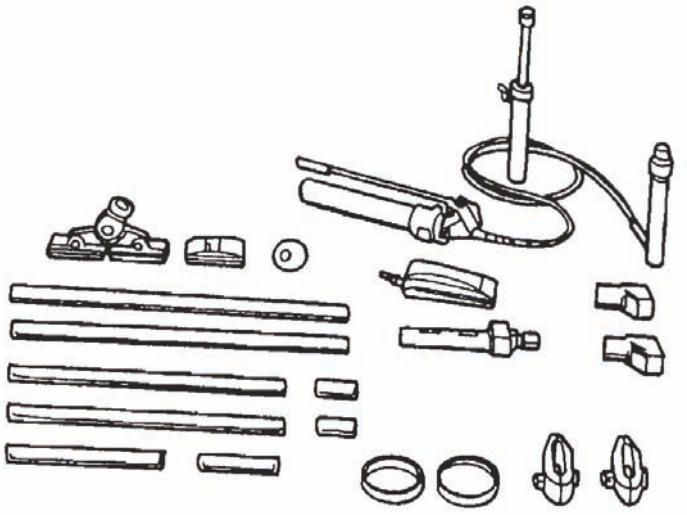
A chain puller or hydraulic equipment is used not only for repairing the underframe, but also for repairing strong areas in panels. They are used when manual force or a the force of a slide hammer is insufficient.

A tower is a simple type that does not have the power of a floor-type system and is used for pulling in combination with a chain puller or similar equipment.

However, when more force is used to repair a panel, it is also necessary to steady the body side. When using manual force the weight of the vehicle on its own is sufficient. However, when using a hydraulic ram or a chain puller, the pulling force can move the vehicle itself. As a result, the force is not used effectively and depending on the direction it can be dangerous.

It's a good idea to use chains to stabilize the vehicle so that it won't move. Attach chains to strong areas of the body, an attach them to floor rails or other solid fittings in the workshop.

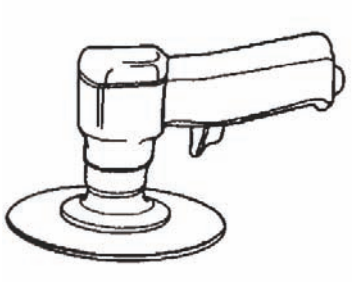
■ Hydraulic ram set



(5) Other types of related tools

Other tools and equipment required when pulling panels are shown below.

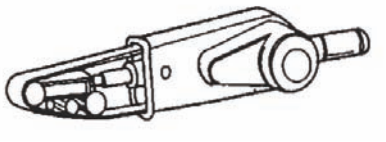
1) Disc sander



A disc sander is used for removing paint and sanding the metal surface when work has been completed. Use paper with a coarse grit of between P24 and 80.

There are single action sanders used specially for removing paint. Paint can also be removed using a variety of other tools, including a sand blaster and special plastic sanders.

2) Belt sander



Use a belt sander for removing paint from small dents and narrow areas.

3) File

Files used on metal are included in body repair tool kits. They are used more to identify unevenness in panel surfaces than as a sanding tool.

4) Guide coat

A guide coat is back powder that is rubbed on the repair site or a black aerosol lacquer paint that is sprayed lightly on the repair site. Humps and dents in the panel surface can be identified by sanding the surface once the guide coat has dried.

5) Air duster gun, cloths, degreasing agents

These are used to clean the surface once work has been completed.

6) Metal surface (zinc phosphate) finishing agent

This one component type creates a thin zinc-plated layer on the panel surface. It is used for rustproofing when repair work has been completed.

The agent is diluted with water and brushed on, and is washed with water when semi-dry.

7) Wash primer

This is usually a two component type, and is a metal surface finishing agent with an added rustproofing pigment. It has much better corrosion resistance and adhesion. Follow the instructions in the manual, as the contents vary slightly depending on the manufacturer.

8) Putty

It's difficult to get a perfect panel by just pulling or hammering. Putty is used to repair tiny bumps and dents once panel work has been completed.

Putty is used to attain the final surface, because in panel beating the surface is restored so that it is slightly lower than the finished surface. It's common for panel beaters to also have to apply and sand back putty.

Putty is a primer coat used to fill dents. The filling depth and fineness of the material are in inverse proportion to each other. Panel beaters use either a metal sheet putty or an intermediate type of polyputty.

Putty is mainly made up of an extender and a polyester resin in order to maintain its bulk. It reacts with a hardening agent and takes a short time to harden. The compounding ratio of hardening agent is 100: 2 – 3. Measure using an accurate measuring apparatus.

■Types of putty and filling performance

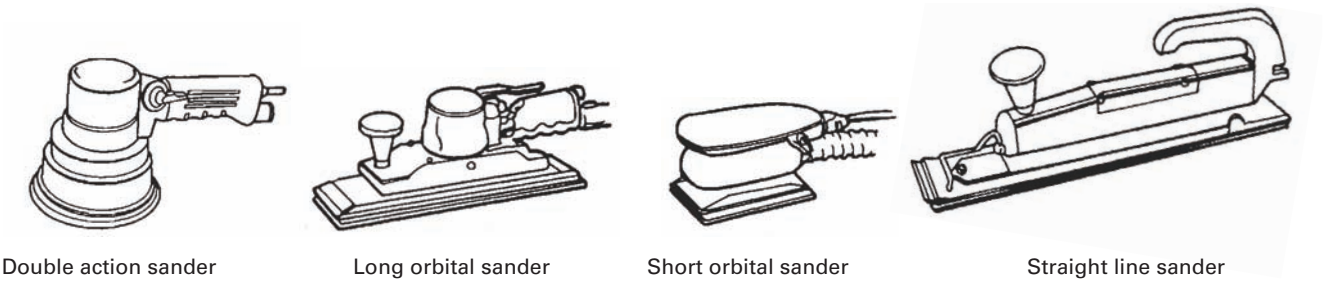
Type		Filling performance	Surface condition	Main applications
Metal sheet putty		to 50 mm	Coarse	Deep dents Sections subject to force
Intermediate type		to 30 mm	Fairly rough	Surface finishing
Polyputty	Thick	10 to 30 mm		
	Medium	5 to 10 mm	Smooth	Repair of puttied surfaces
	Thin	to 5 mm	Extremely soft	Repairs of minor deviation

* These are general examples and values vary according to product

9) Types of sanders

Use a double action sander, orbital sander, straight line sander, etc for plane grinding the putty.

■Types of sanders



Double action sander　Long orbital sander　Short orbital sander　Straight line sander

6. Beating using a hammer and dolly

(1) Principles of repairing with a hammer and dolly

1) How to handle a hammer

The way you hold and beat a hammer when repairing panels is different from beating using a chisel. Even when repairing panels, there are slightly different methods, such as roughing out, bumping and finishing.

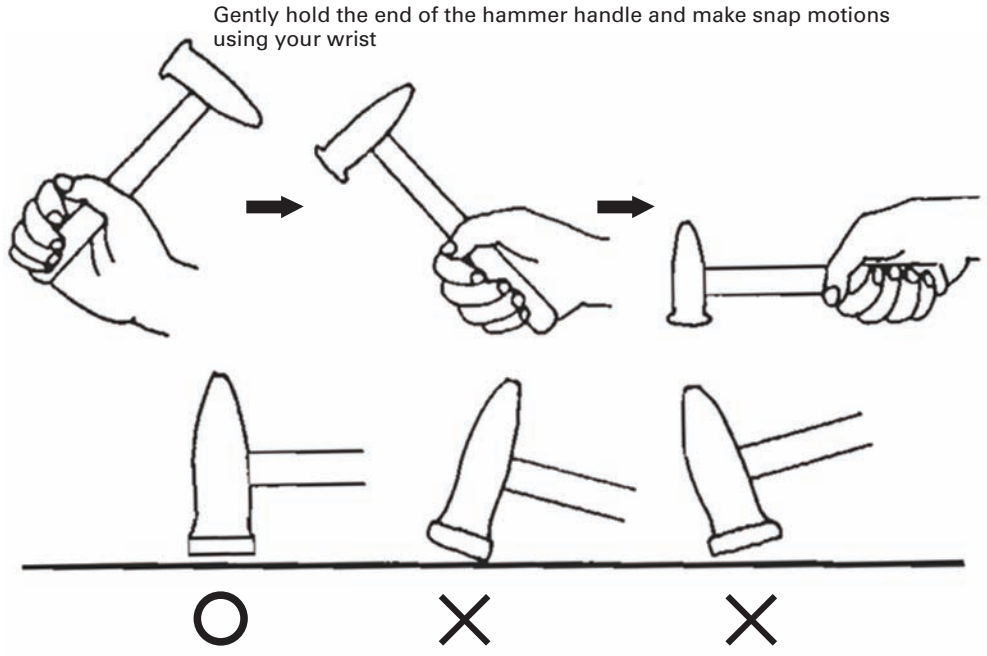
The basic way to hold a hammer is to grip the end applying force with your little finger and gently holding it with your fourth finger and middle finger. To stop the hammer from swinging sideways, lightly press your thumb and index finger against the side. It is important not to grip the hammer too firmly. Grip the handle the moment you hit the panel.

The basic rule when using a hammer is not to use force, but using your little finger as a fulcrum use the weight of the head to make it fall naturally. Don't use only the power from your arm. Use power from the arm only to direct the hammer. When beating repeatedly and fast, make fast snapping motions using your wrist as a fulcrum.

If the face of the hammer or the panel surface are at an angle you will make unnecessary marks on the panel. The basic rule is to hit the panel with the face parallel to the panel. It is not so easy to make marks if the outer perimeter of the panel is rounded.

Try to regulate the number of hits per unit of time and intervals as much as possible. If they become irregular, unstable force will cause a not so good result.

To prevent the panel from stretching, don't continue beating the same spot numerous times.



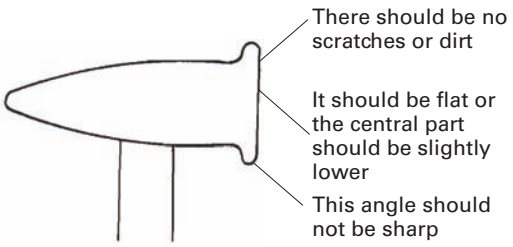
Hit the panel with the face parallel to the panel

2) Hammer care

Use wears down the face and causes marks, so make regular checks and remove dirt etc. Grind the face to tidy it up if there is wear or marks.

Carefully grind the face using a flat file. Put it in a vice and file it from different directions. When finished, plane the edges 1 – 2 mm, and finish by sanding with P400 – 800 sandpaper.

Occasionally check the part where the handle and head are joined and adjust so it doesn't rattle. If it is loose hammering will become unsteady. It is even more dangerous if it comes off.

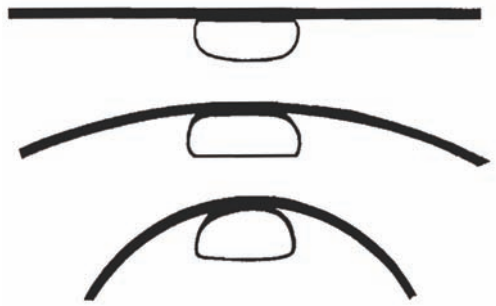

There should be no scratches or dirt
It should be flat or the central part should be slightly lower
This angle should not be sharp

3) How to use a dolly

Hold the dolly so all of it fits in the palm of your hand. Don't grip it, but hold it gently.

As with hammers, the surface of the dolly should always be clean. Remove dirt etc when it appears.

■ How to place an dolly



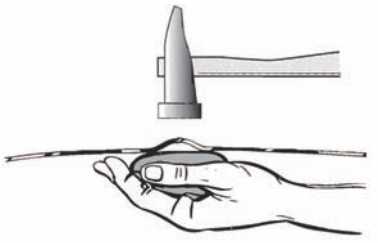
Select the shape that matches the panel surface that is to be repaired

(2) On-dolly and off-dolly

There are two methods of repairing using a hammer and dolly. They are hammer on dolly (on-dolly hammering) and hammer off dolly (off-dolly hammering). Use a combination of the two methods.

1) On-dolly

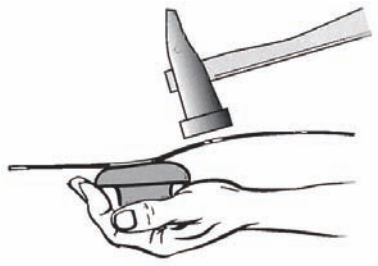
On-dolly is when the panel is between the dolly and hammer. The dolly absorbs the striking force of the hammer, and the panel retracts a little from the dolly. By placing it up against the panel again, it is struck from behind, so the panel becomes flat with force from both sides.



2) Off-dolly

Off-dolly is when the hammer and dolly are not aligned at the panel. Sometimes it is when the dolly strikes the panel from behind. The further the distance between them, the weaker the effect of the beating.

When repairing a panel, start with off-dolly and finish with on-dolly. Take a careful look at the damage, envision what the finished product will look like and hammer methodically until you arrive at something like the finished look. Continuing beating just the dent with force won't restore the shape.



7. Pulling using a stud

(1) Pulling tools

1) Making something to gain leverage

When pulling a more or less flat panel you need something to grab hold of.

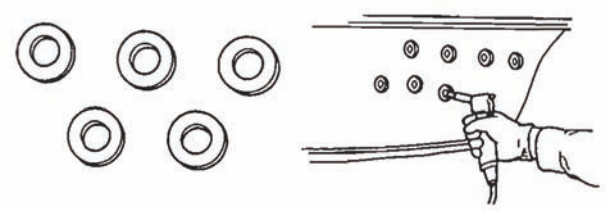
There are three methods: ① Weld something on to the panel surface; ② Make a hole in the panel; or ③ Use a tool that doesn't require something to pull on.

2) Welding on something to gain leverage

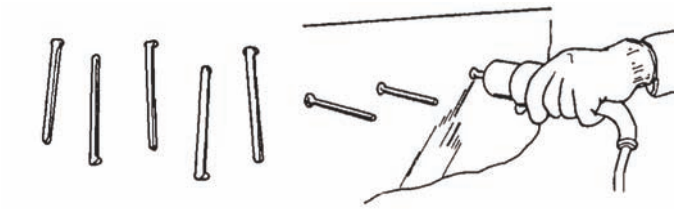
Washers, stud pins, thin sheetmetal, etc are common examples of things welded on. A dedicated stud welder is used for washers and stud pins. The washer (stud) is put in one of the electrodes, while the other electrode is earthed. Dedicated or universal slide hammers can be used to attach the washer and stud, but because with a stud there must be a structure to hold the pin, washers that can be hooked into a hole are more versatile.

A number of washers or studs can also be welded in a row. Connect them and apply force to the larger area.

Although there are some special plate-shaped washers, they are usually used on the cut ends of assembled panels. They are attached using a MIG weld or soldering machine. They are particularly useful when a lot of force is required. A clamp is attached and they are pulled using a large slide hammer or a tower and chain puller.



Attaching washers



Attaching studs

3) Making a hole in the panel

This can be done by ① pulling on a hook-shaped tool hooked into the hole; or ② using the tip of a slide hammer as a drill to make a hole, which is then pulled. Although this is an easy way of getting something to hold on, the area around the hole deforms needlessly and this takes time to repair. Also, if a hole is not filled adequately afterward it may cause rust, and sometimes the putty doesn't adhere properly.

It's not suitable for areas where you can see the rear surface. It also gives the car owner a bad impression. Holes were the common method used before pulling using studs began to be adopted in 1975. This method is hardly ever used today.

4) Tools that don't require leverage

A suction puller that uses the power of a suction cup is a good example of this type of tool.
Other pulling methods include using a solder shaped like a hook or attaching a plastic rod that has been softened at high temperature.
The stud puller mentioned earlier is a tool that uses this method. The tip adheres to the panel.

(2) Panel pulling steps

The basic order of steps for pulling a panel is shown as follows, though this can differ depending on the state of the damage and the tools that are used.

1. Check the damage
   Ascertain the scope of the damage, its relationship to other sections, the severity of the damage, cause, etc. Mark the damaged section if necessary.
2. Remove parts
   Remove pinstripes, lamps and other parts in the area to the repaired.
3. Roughing out
   In cases of severe damage, return the press line or panel shape to as near as the original shape as possible.
4. Remove paint film
   Limit the removal of paint film to as small an area as possible required for attaching a washer, etc.
5. Attach an earth
   To attach a washer, attach a minus electrode on the same panel as near as possible to the repair site, or somewhere where it will not get in the way. First remove the paint from the spot where the earth will be attached.
6. Repairing panels
   Repair the damage using various panel pulling tools.
7. Fixing holes made in the body
   When the repair has been made, if there are small holes left by washers, etc place MIG welder wire (around 0.6 mm) up against the hole, and weld it on from above passing the current through the stud. If once does not fill up the hole, do it a second time.
8. Checking the damage
   Check whether the damaged panel has been finished to a level where body filling can be done. Also check to see whether or not the sheetmetal has stretched.
9. Shrinking
   If the sheetmetal has stretched, shrink as necessary.
10. Sanding the surface
    Sand off traces of the washer on the panel surface. Also check for small marks.
11. Surface finishing
    Rustproof metal surfaces using a zinc phosphate finishing agent or washer primer.
12. Applying putty
    Apply metal sheet putty or polyputty, and sand when dry so that the surface is back like it was before the damage.

(3) Combinations with hammering

Pulling alone is not sufficient to restore panels. Sometimes using a hammer is faster when roughing out. Even at the panel repair stage, it can be quicker to hammer the surrounding area while maintaining pulling force, as this will remove plastic deformation in the panel and restore elastic deformation.

When repairing a small deformation, it is sometimes simpler to use a hammer and dolly. Using appropriate combination of tools, mainly hammers, in this way is a way of shortening work time when repairing panels.

Also, the hammers used do not have to be metal (iron). In some cases mallets and plastic hammers are used to beat lightly in order not to stretch the panel

8. Identifying damage patterns and repair work

(1) Identifying damage patterns

Panels are deformed in a variety of ways. A close comparison shows that no two shapes are the same. Though the shapes might be different, the basic characteristics of damage are the same. Whether the damage covers a wide or narrow area, has shallow or deep dents, and the number or size of creases does not really have much effect on methods or order of repair work.

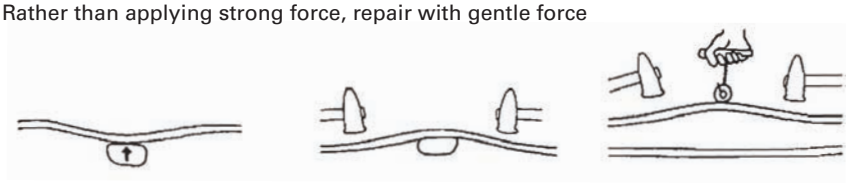
Damage manifests itself in different ways. A look at the types of damage while mindful of work order and methods in the course of everyday panel repair work, reveals there are surprisingly few different types of damage. Identifying damage patterns allows individual deformations to be treated as variations of those patterns, which makes it easy to draw up a work plan. It also shortens work time.

(2) Wide mild deformation

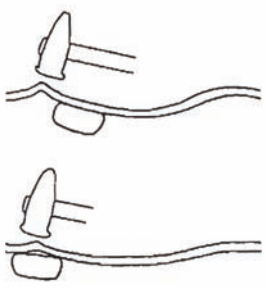
1) Characteristics

Wide mild deformation occurs easily when a not very strong force is applied to panels with near-flat wide surfaces. It is mostly elastic deformation, though partial plastic deformation prohibits the restoring force of the panel.Plastic deformation is easily identified, as sharp angled deformation and peeled paint occur only in those areas.

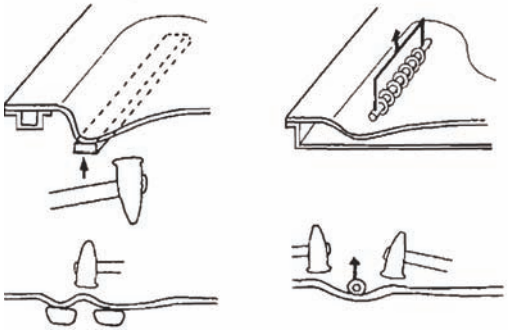
Mild deformation
Rather than applying strong force, repair with gentle force



Partial plastic deformation
Once the plastic deformation is repaired, the entire section will be restored



Deformation taking the form of a step
Rough out by applying force over wider area and starting with off-dolly and then changing to on-dolly hammering



2) Repair work

Restoration is relatively easy because sheetmetal does not stretch very much. Basically, if those areas with plastic deformation are repaired, the other areas will naturally regain their original shape. However, if a dent is formed again when pressing lightly on the restored part, it means that the sheetmetal has stretched at the part where there was plastic deformation. Shrinking then becomes necessary.

At the end of panels and at sites where there are reinforcements, the deformation takes the form of a step. When the impact entry point is nearby, it is possible that box areas in panels will have stretched. For this reason, a method that applies uniform force over a wide area should be adopted to prevent more stretching. One effective method is to arrange a row of washers and pull out the panel.

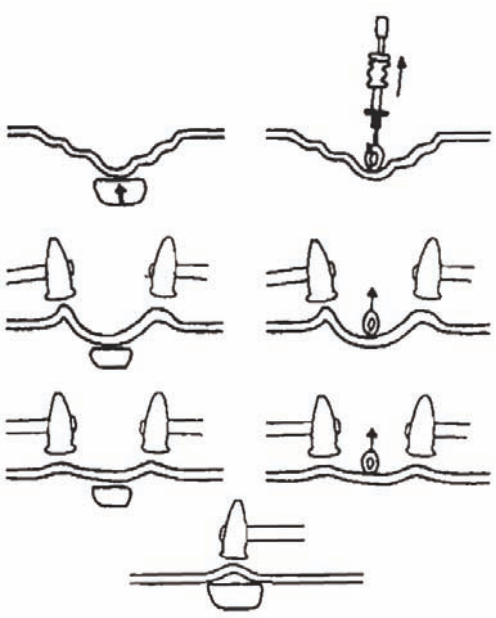
(3) Narrow sharp-angled deformation

1) Characteristics

Stretching has already occurred in narrow sharp-angled deformation in high crowns, corners and highly rigid panel surfaces and there is a risk that more stretching will occur during repairs. Even if you attempt to pull out the center of the deformation, the deformation can easily bring the surrounding area up with it.

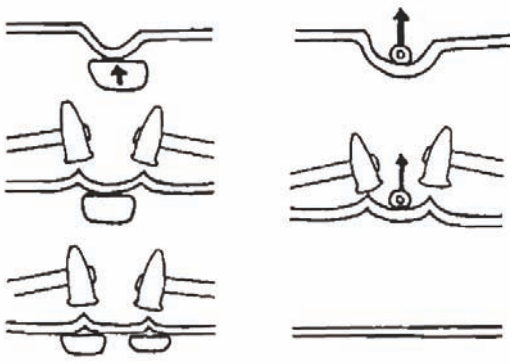
2) Repair work

Keep lifting in check by beating the surrounding area while pulling out the deformation. First pull with strong force, and lightly beat the area that has lifted while maintaining that force. Be careful not to beat too hard as this will cause the panel to stretch. Restore it slowly making sure not to reverse the panel's elasticity. This is done faster by applying force from the edge, not the center of the deformation.



Deep dents

After roughing out with a dolly and slide hammer, repair by hammering, starting with off-dolly and then changing to on-dolly hammering.For panels that have been pulled, hammer while maintaining the pulling force.



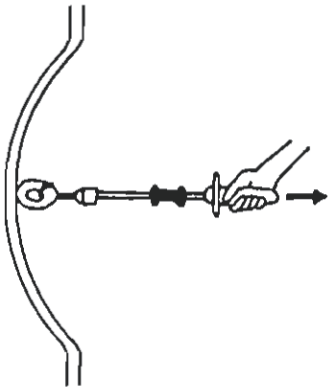
Shallow dents

Either use a dolly from behind or pull out by attaching a washer, and hammer the surrounding area while retaining that force.When the deformation is reduced change to on-dolly.

■ Width of a dent and how to apply pressure

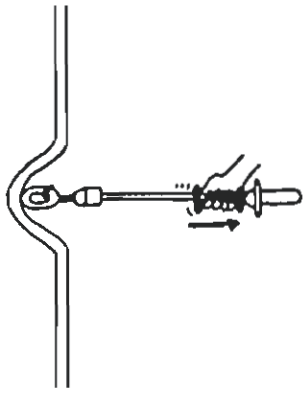
Wide dents

Pull out the whole dent using a slide hammer



Narrow dents

Pull using the reverse movement of the weight



(4) Long narrow deformation

1) Characteristics

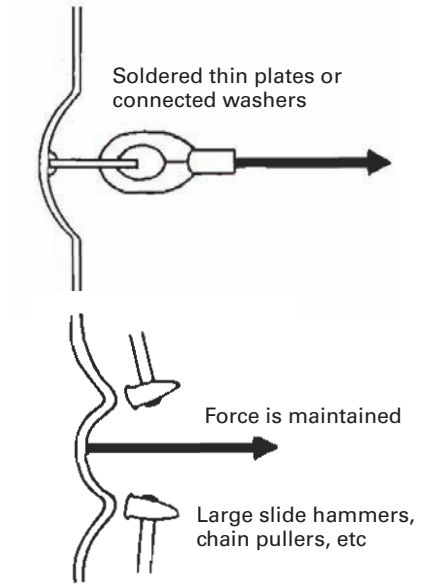
It is common for long deformation to be elastic deformation and for short to be plastic deformation. Accordingly, don't apply much force to lengthy deformation (don't beat much with a hammer), and repair the damage in the short direction.

2) Repair work

Pulling requires a relatively large amount of force. Since working from the center of the deformation will stretch the sheetmetal, if the deformation is long repair it little by little from both edges moving toward the center along the longitudinal direction of the panel.

Conversely, if the deformation is short, working on parts will stretch the sheetmetal. Applying large force to the center of the damage in short bursts will be quicker in some cases.

Rough out first by pulling with stronger force, and repair by hammering while maintaining the pulling force



(5) Creases

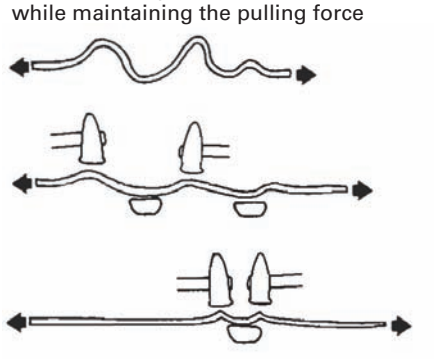
1) Characteristics

This kind of deformation occurs when force is applied in a lengthwise direction to the panel surface. Although if the damage is severe the panel should be replaced, restoring this damage is not as difficult as it looks. Because all of it is compressed, apply force so as to stretch it to its original length.

2) Repair work

If this type of deformation occurs in a bolted on panel, repair will be easier if the panel is taken off. If force is applied to stretch both ends of the panel it will regain some of its original shape. If force is removed at this point, because it will shrink for a second time while deformed, stabilize the shape by beating the sharp angled part.
Panels with this damage are perfect for practicing beating skills.

Pulling from both ends to stretch the creases and repair the deformation while maintaining the pulling force



9. Sheetmetal shrinkage

(1) Causes of stretching

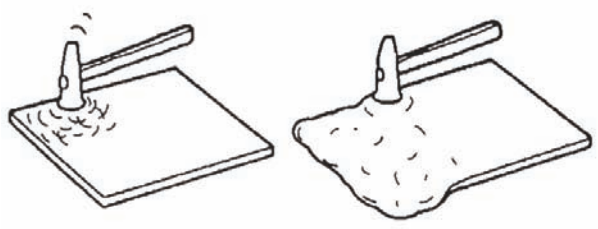
When comparatively soft metal like gold is beaten a number of times it will become thinner and its area will increase. This is called metal ductility.
Sheetmetal has the same property. As a result, when an impact or force is applied for making a repair, it will get thinner and the area will increase. This is sheetmetal stretching. Because when part of a panel tries to stretch the surrounding metal stays the same, it can't increase its area. As a result, that part of the sheetmetal becomes surplus. It changes from its original shape by rising a little and rumbles when pushed.
To repair the stretching, this part of the sheetmetal has to be shrunk. Shrinking is done by using the stretching and shrinking of metal that occurs due to temperature change. It is an important task that has a huge effect on the finished quality.

(2) Detecting and preventing stretching

Shrinking is a technically difficult part of panel repair. A damaged panel has varying degrees of damage and most have a part that has stretched. In restoration it is necessary not to make the stretching any worse and to keep it to a minimum. In details, ① do not apply stronger force than necessary; ② when beating do not keep repeatedly beating the same spot; ③ and make the repair as simple as possible.
Often it is not possible to identify a stretched part from its appearance alone. In order to find the stretched part either run your hand over the sheetmetal or press the metal with your fingers.

■ Panel stretching

When force is applied to metal it stretches and expands
Hammering will stretch the sheetmetal



Even a stretched area that looks as if it has been restored to its normal shape will rumble when you run your hand over it.

1) Feeling by hand

Run the palm of your hand from the undamaged part of the panel over the part that has been repaired. The part that has stretched will bulge slightly.

Sometimes parts along the press line or on the edges of a panel that have nothing to do with the repair will bulge. This is caused by stretching of the part being repaired. This will naturally correct itself when the stretching is fixed.

2) Pushing

Push the repaired part with your fingers. The biggest dent will be the center of the stretching. If the stretching is severe it will make a rumbling noise. If all parts feel the same when pushed, it means there is no stretching.

If another site deforms when you push it means that the part that deformed has stretched.

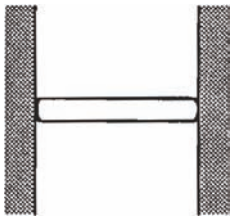
(3) Principles of shrinking

Metal expands when heated and shrinks when cooled. Shrinking is applying this principle to sheetmetal that has stretched.

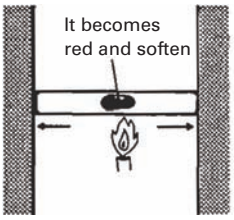
When stretched metal is heated the hot sheetmetal will try to expand, but it won't be able to because the surrounding metal is at room temperature. Expansion will concentrate in the stretched thinned area. If it is instantly cooled at this point, the stretched surplus area will lock up. While the metal is hot, beat the perimeter of the stretched area as if shifting the sheetmetal to the center. If the perimeter of the stretched area is large, repeat the same action a number of times.

Shrinking should be done quickly. When heating, heat as small an area as possible to a high temperature. If it takes too long and the heated area widens, the whole area will bulge and render the task meaningless. When cooling, quickly cool the hot area while it is still hot. If it is cooled slowly, the sheetmetal that has collected in the stretched area will widen and you will be back where you started.

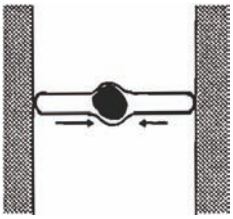
■ Principles of shrinking



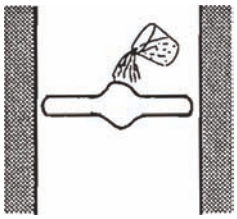
① Suppose there is an iron rod whose ends are both blocked by walls



② When the center of the rod is heated, the heated area will soften and the entire area will bulge and try to lengthen.



③ Because both ends can't lengthen as they are blocked by the walls, the swollen part will shift to the area in the center that has softened



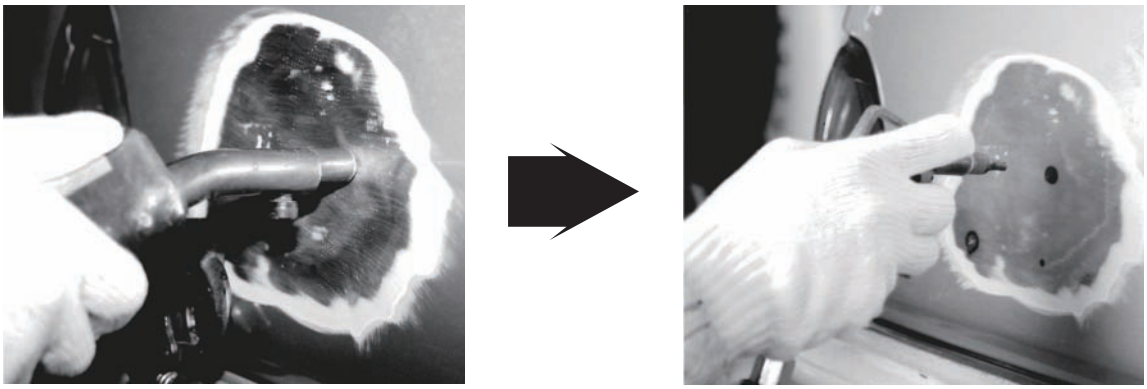
④ If the metal is cooled rapidly while in state ③, the iron rod will try to return to its original length. However, the total length will shorten because the area in the middle will have cooled and locked up.

(4) Order of tasks

1) Heat shrinking using a welder

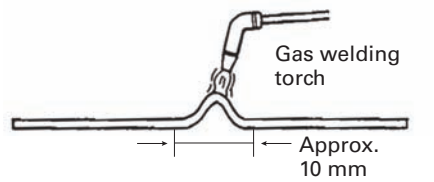
It is usual to carry out heat shrinking using the shrinking function of a spot welder or stud welder.
If the stretched area is not large, turn on the welder while pushing the shrinking electrode rather hard against the center. When you take it away cool it straightaway with an air duster gun.
If the stretched area is large, begin at the perimeter of the stretched area and move toward the center in a spiral motion.

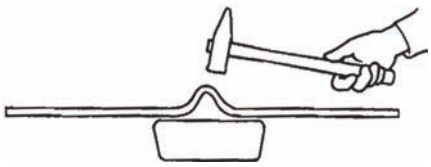
■ Heat shrinking using a welder

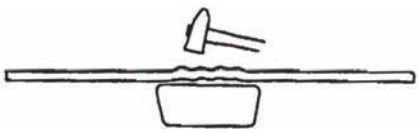


2) Shrinking using an oxy-acetylene welder

Gas welding was the main method used for shrinking before heat shrinking became common. However, this requires a lot of practice. With the gas flame, heat the center of the stretched area so that a spot around with a diameter of around 10 mm heats to a red color. Next, using a hammer and dolly beat the sheetmetal so as to shift it from the perimeter of the heated area towards the center. The secret is not to beat too hard. Then immediately cool the heated area with a water-soaked sponge or cloth. Hammer quickly, because if the metal cools while hammering it won't have any effect.
Using this method once will shrink an area with a diameter of approximately 10 cm. If the stretched area is large this has to be done a number of times. In such cases, first shrink the center of the stretched area and then the surrounding area.







Chapter 6 Sheet metal treatment

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1. Rustproofing

(1) Causes of rust

As seen in the iron ore refining process, iron used to make sheetmetal exists in the natural world as ferric oxides (FeO and Fe_20_3). In other words, iron itself is an unstable element and exists joined to oxygen. This is why oxygen is removed when making iron materials. Conversely, it means that iron combines easily with oxygen.

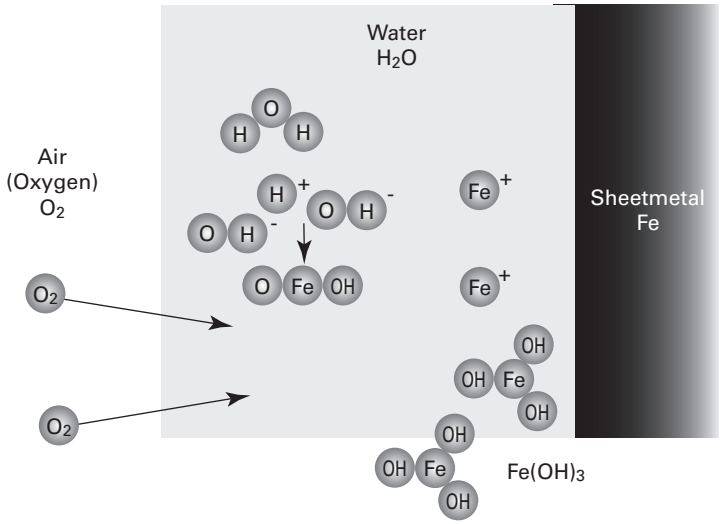
Oxidation is rusting, and oxygen which causes rusting is in the air (makes up around 21% of air. Most is nitrogen (78%)). Oxygen is also in H_20, or water, the cause of moisture, that is in the air. Rust is accelerated when salt (NaCl) is added, and rust forms easily in coastal areas exposed to the sea and in regions where anti-freezes are used.

If iron is left it will combine with oxygen and rust. In the case of iron, rust will migrate from the surface to the inside. This causes holes, reduces strength and makes iron brittle.

Painting is a means of preventing rust, and rustproofing is improved by applying a coat of sealer or an anti-corrosion agent.

Air	Oxygen or moisture in the air condenses and adheres due to temperature difference.
Moisture	Rain, car washing
Salt	Rust occurs when chlorine is present. Coastal regions and regions where anti-freeze is used.
Pollutants	Sulfur discharged from factories becomes sulfurous acid gas, and iron rusts even more when exposed to this gas. Acid rain also plays a part
Difference in electrical potential	When there is a huge change in air temperature, if iron comes into contact with a different metal an electric current flows and the positive side rusts Iron—Aluminum → Aluminum Iron—Zinc → Zinc

■ Causes of rust



When moisture is attached to a sheetmetal, iron will seep into the water as ion, combines with OH ion in water and becomes ferrous hydroxide $Fe(OH)_2$. If oxygen is further bonded, it becomes ferric hydroxide = red ruster $Fe(OH)_3$.

(2) Rust prevention

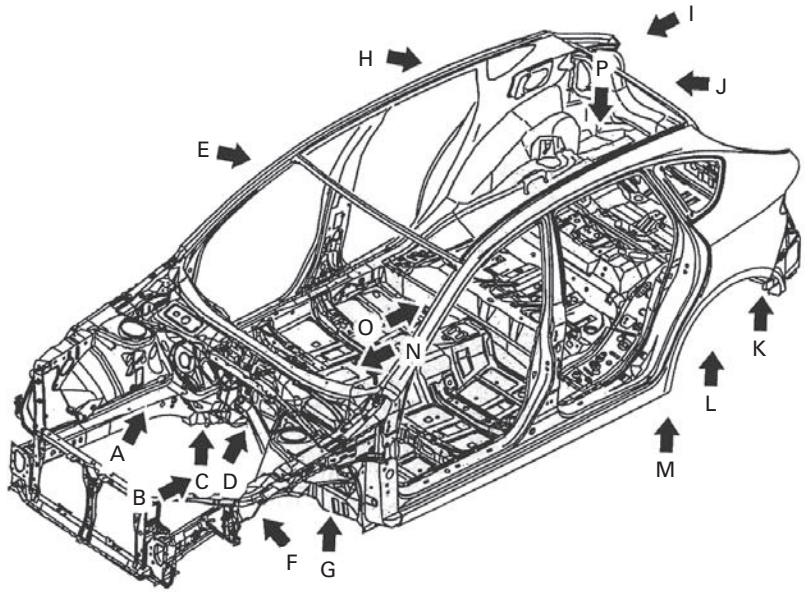
1) Sealers

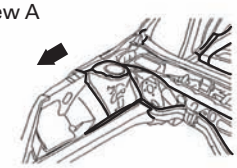
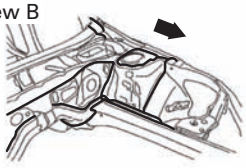
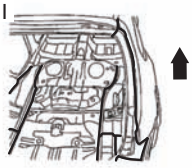
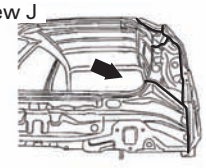
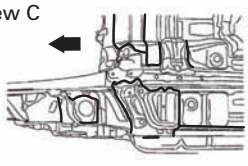
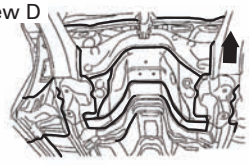
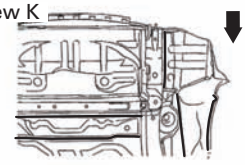
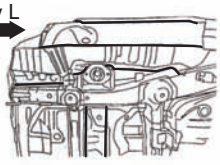
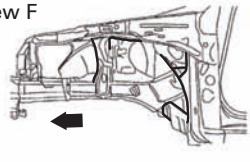
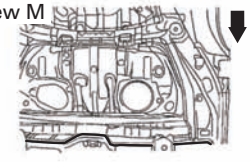
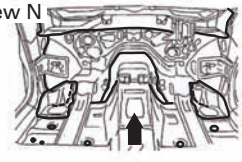
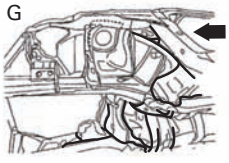
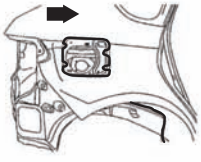
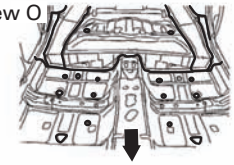
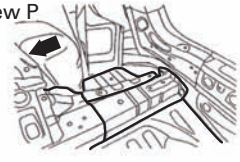
Sealers are mainly coated on joints to prevent water from getting in.

Check the body repair manual to identify the sites where sealer has been used, and if repairing a panel where a sealer has been used make sure you seal the same site using a designated sealer or a repair product with the same performance. Make sure you seal underframe parts.

Hood, door, and tailgate panels are already sealed.

■ Examples of sites where sealers are used



View A 	View B 	View I 	View J 
View C 	View D 	View K 	View L 
View E	View F 	View M 	View N 
View G 	View H 	View O 	View P 

2) Anti-chip coatings

Sides sills and other sections are coated with an anti-chip coating to prevent rusting caused by peeling paint film caused by flying stone chips. Sealers are thick and form a moderately uneven painting surface.
Since there are different kinds, check the model in the body repair manual and apply the same paint treatment using a similar repair product.

3) Rustproofing wax

Rustproofing wax is applied to the inside of pouch-type underframe parts, hinges (hood, door, rear gate), and some side sills.
Check the body repair manual to identify which sites have been coated in the body repair manual, and if repairing a panel that has been given a coating of rustproofing wax, rustproof using the designated rustproofing wax or a repair product with the same performance.

4) Undercoat

Undercoat is applied to underneath the body, suspension, etc.
Check the body repair manual to identify which sites have been coated, and if repairing a panel that has been given an undercoat, apply an undercoat to maintain the designated thickness using the designated undercoat or a repair product with the same performance. Mask around the sites to prevent the undercoat from adhering to areas besides the designated sites.

2. Surface preparation

(1) Sandpaper

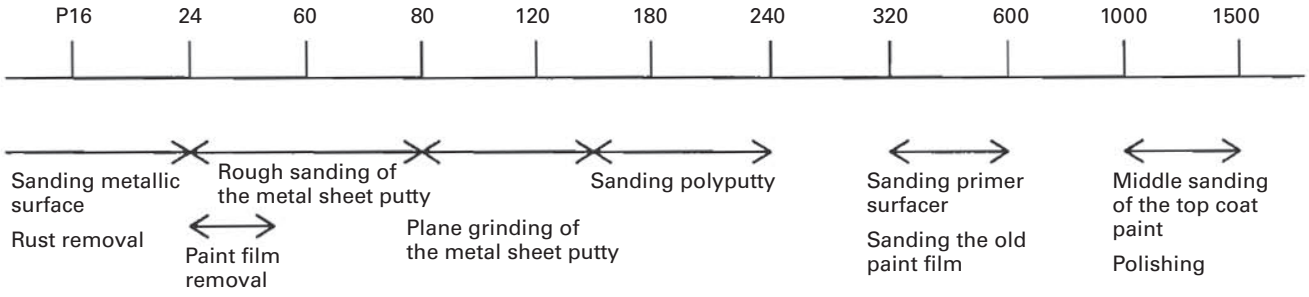
Sandpaper is used for surface preparation. This can be done using a sander or attaching sandpaper to hand sanding pads (holders, blocks). There is adhesive or Velcro on the underside.

Since the shape, size and positions of the suction holes for suctioning putty dust vary according to the type of sander used, use sandpaper suitable for the conditions.

In addition to there being different kinds of paper for different materials and uses, there are different grits. The lower the number the coarser the paper. Paper with a high number has a fine grit. Grades with a P comply with the industry standard, so different makes of paper will be the same.

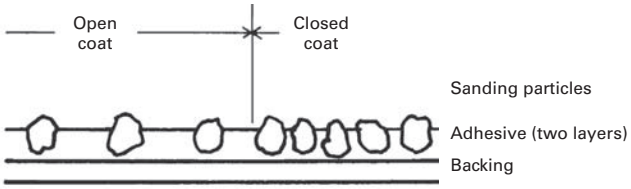
The basic rule when using sandpaper is to start with a coarse grit size and move gradually to a finer grit making sure you do not a miss grit size in between. This is because you will have to get rid of marks left by the paper.

■ Sandpaper grades



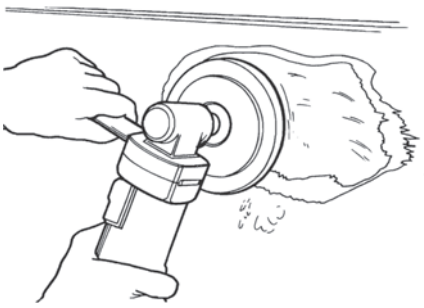
* Differs according to colors or paint to be used

■ Structure of sandpaper



(2) Surface preparation procedure

1) Removing paint film



Paint film is removed when pulling panels in order to earth a tool or to attach a washer.

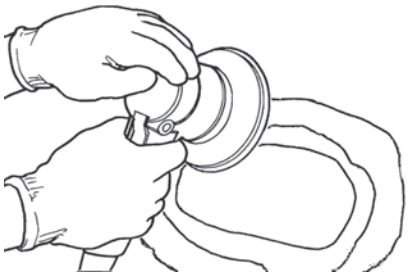
When the repair has been made, remove paint film from other damaged areas for surface preparation. Use a disc sander for this task.Use sandpaper with a grit size of P60 to P80.

Place the disc sander lightly against the painted surface, hold it at a 15 – 20˚ angle, and sand evenly. If you push too hard against the surface the heat of friction will cause the sheetmetal to deform.

When repairing a small mark it is okay to use a double action sander and start with a grit size of P120.

Since sanding will produce dust, wear a dust mask and safety glasses.

2) Feather-edging



Feather-edging is tapering the edge where the metal surface that appeared by removing the paint film and the paint film meet. Use a double action sander and P80 to 120 sandpaper. Use a hard pad.

Surface preparation is an extremely important car repair process. If the job is not done properly, sandpaper grains, leftover putty and blisters will cause paint defects.

When feather-edging, taper off over a wide area. Hold the dual-action sander gently, and sand applying the entire surface of the pad.

When finished, rustproof the surface by applying a metal surfacing agent or a primer. Sanding the surface of rustproofed sheetmetal will remove the zinc-plated layer, so this has to be done again.

3) Applying putty

① Handling putty

Stir the putty before using. Use a special stirring stick so that impurities don't get mixed into the primary agent. For the hardening agent in a tube, push down hard and mix it in with the cap firmly on.

Make sure you put the lid on the primary agent can so that dust and other impurities don't get inside. Commonly omitted from instructions on the container is that there are putties for different temperatures (standard, summer and winter). Once you have opened the can use it up as soon as possible. When it is cold, you can dip the can in 60 ˚C hot water to soften it. Do not use an infrared drier.

The primary agent to hardening agent is based on weight, so measure accurately using scales. If you have a good feel for the correct quantity it is also okay to measure the quantities yourself.

■ Stirring putty

Stir the putty sufficiently before using

② Timing for applying putty

When repairing panels with tools, the extent to which a precise surface is achieved depends on the workshop's quality policy and the skills of repairers. Applying putty when as clean surface as possible has been made will shorten later processes. However, finishing a sheetmetal surface so that it is perfect requires much work and a lot of time. The more you hammer or pull out a panel the more the panel will stretch. This will disrupt later processes.

It is possible to use putty to repair dents that are up to 10 – 15 mm deep. There should be no stretching. Different putties are used depending on the depth of the dent. Stretched areas should be fixed before this stage.

③ Basics of applying putty

Different putties have varying limits for the depth to which they can be used. Ascertain the limit of the thickness of the putty you are using. However, the thickness stated in the specifications is not achieved with a single application. It refers to the allowable final thickness after you have gradually built up the putty.

A single application will fill a depth of around 10 mm. Apply the putty in two steps if the dent is deep.

Keep the surface filled with putty as clean as possible. If there are obvious applicator marks, sanding will take time and it will be more difficult to create a smooth surface. When the required amount has been applied, put the spreader down and gently smooth the surface to get rid of the applicator marks.

④ Preparation

Before applying putty, use a duster gun to blow away dust from the repair site and use a cloth containing a degreasing agent to remove dirt and oil. If putty is applied on top of dirt, sand dust or oil, there will be problems when painting.

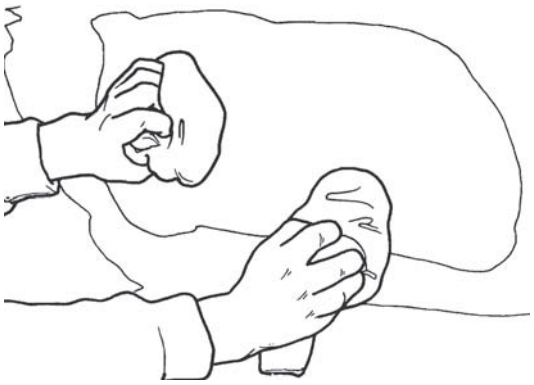
Putty or polyputty used after body repair is a two-pack base coat. Place only the required amount of the correctly mixed filler and hardening agent on a mixing pallet and mix with an applicator. When you need a lot of putty, mix and apply it more than once. Mixing a lot of putty at once will take time and the application will also take time.

Mix the putty evenly and quickly. The primary agent of the putty will start hardening rapidly as soon as the hardening agent has been mixed in. Mix the filler without letting air get inside. If air gets in it is possible that there could be problems with painting later on.

Spread the hardening agent over the putty, rub it in and mix it by reversing directions until an even color is formed.

■ Degreasing

Wipe the site with a cloth containing a degreasing agent and then wipe with a clean cloth.



⑤ Technique

Putty is applied in three steps: ① folding; ② building up; and ③ smoothing. First, apply the putty with the applicator upright as if lightly folding. This will improve adhesion to the sheetmetal. Next, coat it holding the applicator at a 30 – 45˚ angle. Apply a number of times as necessary for dents. Do not apply thickly in a single application. Air could get in or holes could form. Lastly, clean and put aside the applicator, smooth the surface and get rid of the applicator marks. Remove putty that has spilled over to the surrounding area.

The surfaces of panels to which putty is applied have a variety of contours. Use the most appropriate applicator for the surface.

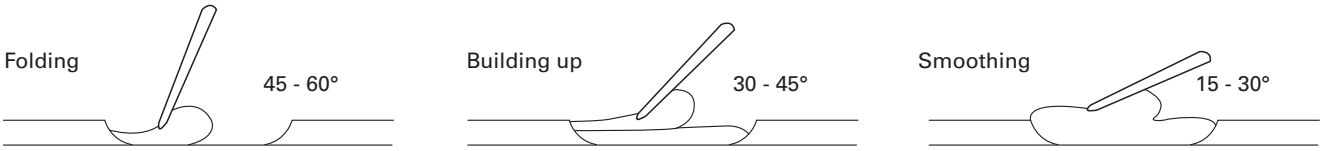
Choose a hard applicator for a flat surface. A soft applicator is suitable for slightly curved surfaces. For a steep curve, the filler won't follow the crown unless an elastic applicator like a rubber applicator is used.

When applying filler to a curve, it tends to be thick on the edges and thinner in the center. If spread too thickly sanding will take time. If spread too thinly filler will have to be applied again after sanding. Conversely, since reverse crowns are hard to sand, apply a minimum amount.

For press lines, don't apply all at once. Check the shape and using the line as a border, apply putty twice, once above the line and once below the line.

Attach masking tape next to the line on the upper side of the area being filled. When you have applied putty below, peel off the tape and apply putty to the top. If the putty is dry, you can also attach masking tape on the lower side.

■ How to apply putty



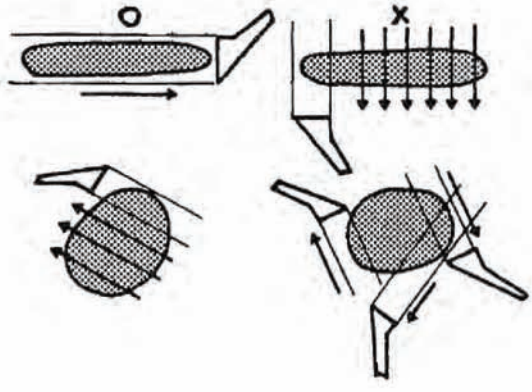
① First apply the putty very thinly and fold

② Apply the putty repeatedly as necessary

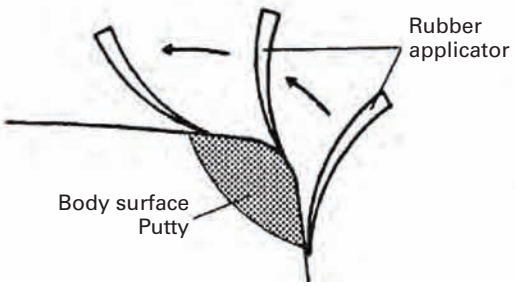
③ Finally lay down the applicator and smooth the surface

■ Technique for applying putty

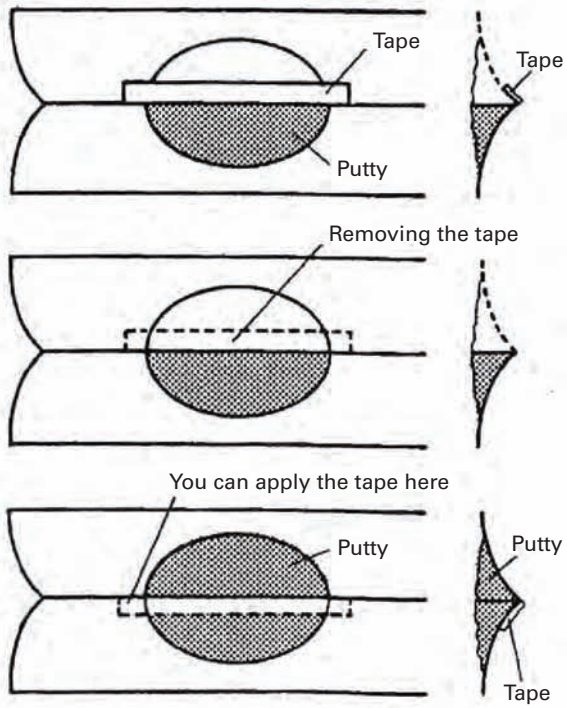
Shapes of the damaged sections and applicator handling



Applicator handling a the tight curves



Applying putty at press lines



⑥ Drying putty

Even when drying naturally, putty does not take much time to dry as at 20 ˚C it will dry in around 20 minutes. An infrared-type drier can be used to fasten the drying process. However, care is needed as rapid heating and extreme temperatures can cause paint to crack or peel. Adjust the temperature by placing some distance between the drier and the site.

If the temperature is 5 ˚C or below, drying will take longer. Not only heating up the body or the putty, but also force dry instead.

Putty becomes hot when it is reacting. Thick areas will dry first because drying is hastened under reaction heat of 100 ˚C or more. Therefore, check how the paint is drying by scraping a fingernail across surrounding areas where the putty is thin. This shows that sites with thin putty have poorer adhesion than sites in the middle.

Because high tension steel is not thick it is possible that shrinking or distortion can occur as a result of necking when the putty dries. However, there are putties with less solvent and those in which another substance swells to compensate for the solvent evaporation.

4) Sanding putty

Sanding putty consists of three steps: rough sanding, plane grinding and scoring. When applying the same putty or polyputty, scuff after the putty has been smoothed. Plane grinding is the hardest technique, and ultimately is the domain of a paint technician.

Rough sand with a sander and do the last of the plane grinding by hand to produce a smooth surface.

A double action sander, orbital sander, or straight sander can be used for this. There are different sizes and different models for different skill levels. Use a double action sander or orbital sander with a high number of oribt diameter. A sander with a large eccentric shaft has excellent sanding power.

The sander is moved differently depending on the work site and shape. For flat surfaces, don't move the sander in the same direction, but move it back and forth, right to left etc at various angles. Use P120 – 180 paper.

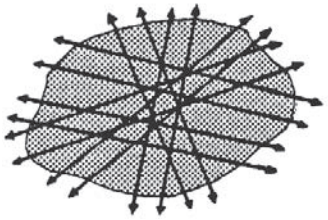
For a slightly curved surface, move the sander in a straight line at an angle to the vertical direction of the body. A straight sander and long orbital sander are suitable for this. In the case of a long thin repair surface, it is best to work in a lengthwise direction when applying putty and sanding.

Press lines are treated the same as when applying putty. Use masking tape to protect one side of the line while sanding the other. Sanding the surfaces on both sides of the line will naturally produce the press line.

This method can also be applied to gently curved surfaces. Surface finishing can be done quickly by dividing the top and bottom in two, sanding each part and lastly smoothing the middle.

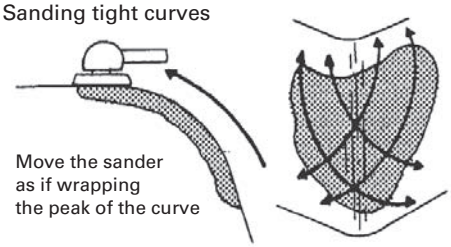
■ Technique for putty sanding

Sanding flat surfaces



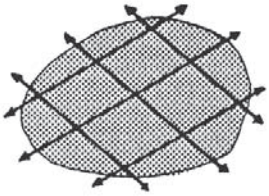
Move the sander to all the directions of the putty surface

Sanding tight curves



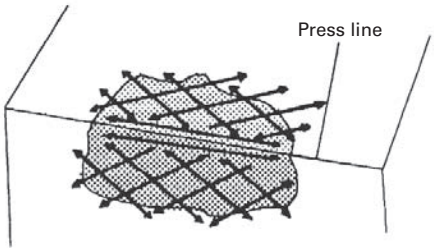
Move the sander as if wrapping the peak of the curve

Sanding gentle curves



Move the sander to a constant direction at an angle

Sanding press lines



When sanding, consider it as completely different surfaces that are separated by the line

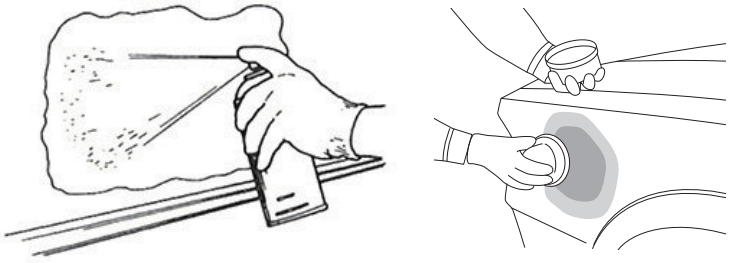
5) Checking the finish

For panels like outer panels of the doors and rear quarters where the vertical direction is curved but the front-back direction is nearly flat, check surface finishing using a straight-edge. Use a straight-edge which is long enough to straddle the filled area, put the ends on the unaffected surface and move the straight-edge up and down. If the gap between the straight-edge and the filled surface is regular, the surface is almost smoothed.

If a guide coat has been applied to the surface of the putty beforehand, the remaining black spots will reveal the high spots and low spots.

Although it is common for panel beaters to do the repair up to around the sanding stage, if a further surface finishing stage is required, use this sort of guide coat and do the final finishing by hand with fine grit paper.

■ Guide coat



Chapter 7 Damage analysis

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1. Damage diagnosis

(1) Circumstances of accident

Check information concerning the circumstances surrounding the accident.

The "5 W" and "1 H" approach is the best.

- When: Time the accident occurred
- Where: Site and road conditions
- Who: Driver, passengers
- What: Another car or object
- Why: Cause of the accident
- How: situation at the time of the accident, speed (relative speed), load, impact site, angle, etc

(2) Order of diagnosis

First, check the damage in a light area where there is a hoist, jack, lamp, measuring tape, etc

Start with the whole vehicle and then look at individual sites.

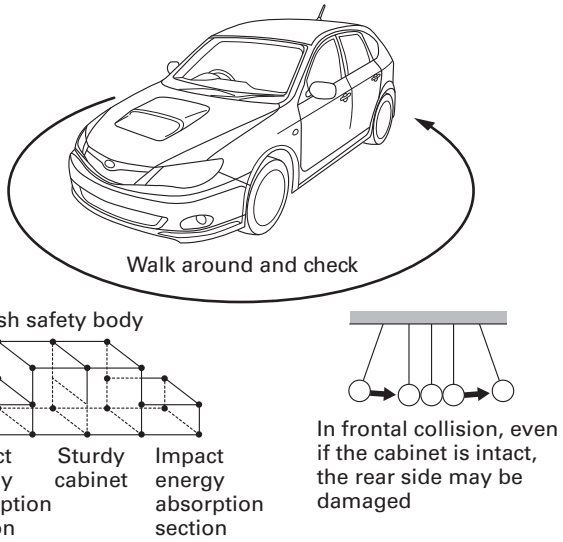
- Overall appearance: Walk around the vehicle. Look for entry sites and around the damage. If there is more than one site, check the order of entry and whether there is any pre-existing damage. Check to see whether it conforms with the information you have received and whether there are other sites that haven't been spotted.

  Look for not only areas where damage has been caused by direct contact, but also secondary damage and inertial damage caused by passengers or luggage.
- Damage sites: From the appearance of the damage sites deduce whether the damage is restricted to the outer panels or whether it involves inner panels and the underframe.

  Stand a certain distance away from the vehicle, and consider the site where the force of the impact hit the vehicle, the directions in which it spread and the strength.

  It's not possible to make effective repairs if you don't have a firm grasp of the location and extent of the damage.

■ Checking the damage

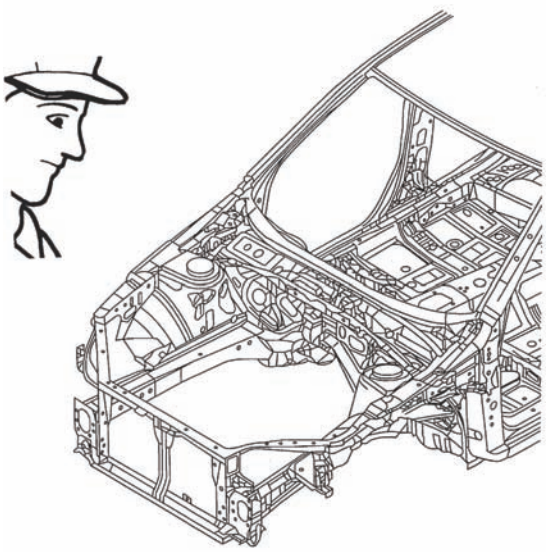

Walk around and check
Crash safety body
Impact energy absorption section
Sturdy cabinet
Impact energy absorption section
In frontal collision, even if the cabinet is intact, the rear side may be damaged

(3) Checking measurements

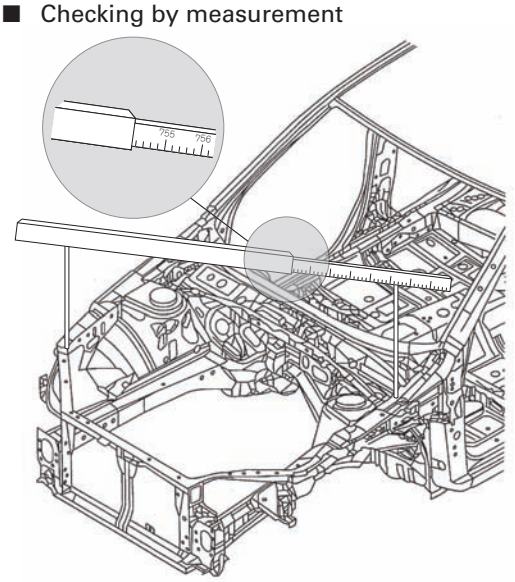
When checking the extent of damage make a visual check and use measurements.

Damage to the underbody can be identified by taking measurements using a jig or centering gauge. For the upper body, measurements alone can sometimes not be enough. Because a visual check is not precise, you should finally determine the dimensions of each site using a tram gauge or measuring tape.

■ Visual check



■ Checking by measurement

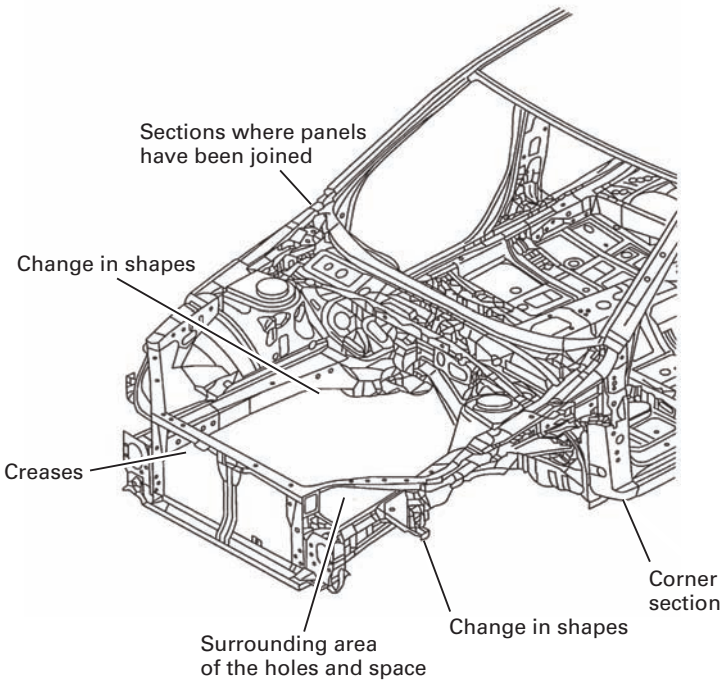


2. Underframe construction and damage

(1) Damage prone places

Because body strength varies depending on the area and impact absorption construction is used in some places, each part of a vehicle has spots that are prone to damage. If you check these spots you will get an idea of how far the force of the accident has traveled.

Damage prone areas are areas where stress concentrates. They include around punch holes, corners, places where the thickness of a member or reinforcement changes, and where panels have been joined.



(2) Easily overlooked damage

Huge bends and dents are easily seen. However, if there is not much deformation it can sometimes be difficult to spot it with a visual check. For this reason, it's only natural that you check by taking measurements. There are some points to look out for when making a visual check.

For example, when a frame (member) is bent, it can be hard to tell from the outer side of the direction of the bend. In such cases, if you check the inner side too you will be able to tell from the creases. Conversely, even if something does not look to be bent, if there are creases on the surface it will be bent and the side with the creasing is the inner side.

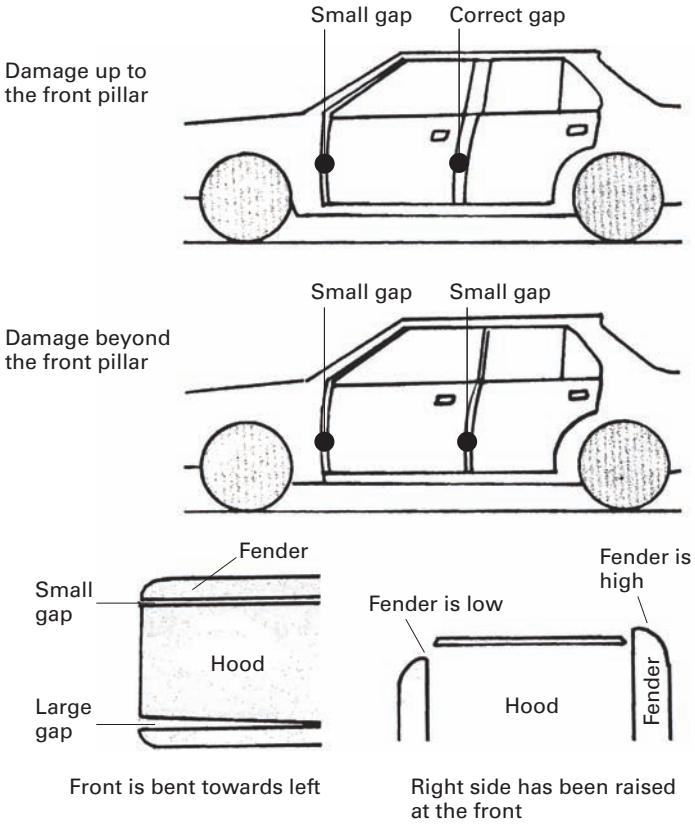
If deformation to the side frame, for example, is small compared with the overall damage, check to see whether the side frame has gone into the toeboard.

(3) Arrangement of opening parts and body damage

You can tell deformation from the gaps between the doors, hood and adjacent panels. If the gap on the front side of the front door is narrower even if the gap on the other side is normal, it means that the damage didn't go further than the front pillar. If the gap at the rear side is also narrower, it is highly likely that deformation has occurred in the roof and side sills.

If you look at the gap between the front fender and the hood, you can detect deflection in the front body. For example, if the right of the front end is narrow and the left is wide it means that the body is bent toward the right. If the right of the hood is high and the left is low, it means the right side has been raised.

■ Distortions between the gaps of the panels and the body



(4) Front-end collision and damage

Damage to the front of vehicles is the most common.

When impact is light, it first pushes the bumper and deforms the front side member via the bumper stay. Depending on the impact site, deformation can also occur in the front grille, front fender, radiator panel and hood.

When impact is heavy, the whole of the front fender will be pushed in, the gap between it and the door will become smaller and the hood will get stuck on the front panel. The side member will bend near where it is attached to the suspension members, and if there is a lot of deformation even the toeboard near the site where the member is attached will deform. If force travels as far as the front pillar, the back-end of the door will sag. There will also be more damage to the wheel apron.

(5) Side collision and damage

The type of deformation varies depending on the shape of the body and the area where the force was loaded. When there is a huge impact not only the doors and pillars, but also the floor and roof will deform. Because force is loaded in the direction in which the entire side compresses, the wheel base may be shortened and it may affect the front fender and rear quarter. The floor is prone to deformation on the inner side of the site where the side sill is attached and where the center tunnel rises up.

(6) Back-end collision and damage

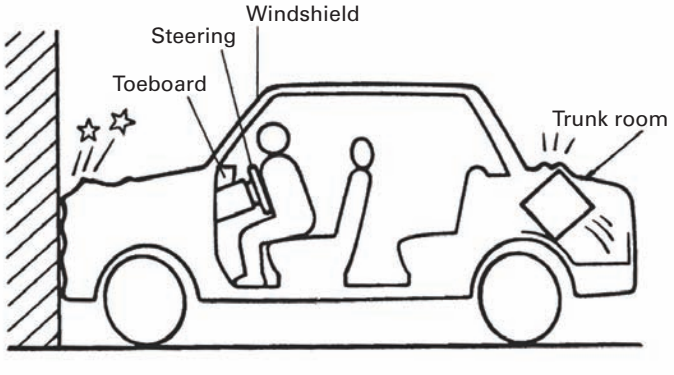
If the impact force is minor, damage will be limited to the rear bumper and around the rear skirt. However, if impact is greater, deformation will occur in the rear floor pan, rear side members and roof. In the case of the quarter panel, if impact is minor, the fender area will bulge, and if impact is major the area up to the rear door will be bent. An impact absorption structure is mainly used on the corner of the rear side members. In front-wheel drive vehicles, particularly those with a rear gate, the simple body structure around the back end means that there will be greater deformation for the amount of impact force. In some cases, deformation will extend to the center area and the center pillars.

(7) Damage caused by secondary impact

Even in the absence of direct force, movement by the passengers, luggage, engine etc caused by an impact can cause damage. This is called secondary damage. For example, the movement of luggage in the trunk can cause damage.

The radiator, engine and transmission mounts and base of the gearshift can be deformed by engine movement. If impact is major, the inertia force of the vehicle may cause damage to comparatively hard parts. This occurs in the roof and side sills.

■ Damages caused by luggage and other



3. Damage to outer panels

Because damage to outer panels appears in the form of dents, buckles, scratched paint film etc, it can be diagnosed by a visual check and by feeling with the hand.

There are two types of damage to outer panels. There is plastic deformation where they have received direct impact, and there is elastic deformation which occurs indirectly in the surrounding area.

Determining the area of the damage and the type of deformation can affect repair efficiency and time. The reason is that by first repairing directly damaged parts where plastic deformation has occurred the elastic deformation in indirectly damaged areas will largely be corrected. This means that restoration will take longer if you repair parts with indirect damage first.

Chapter 8 Removal and fitting of parts

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1. Hand tools

A variety of tools are used in vehicle repair. Below is an explanation of general-purpose tools, such as those used for disassembly, assembly and cutting.

(1) Types of hand tools

Hand tools are tools that don't use electricity or compressed air and for which human strength is used. The functions of tools are mostly based on human hand movement. They can be divided into three categories according to their function. Namely, there are tools that ① twist; ② grip; and ③ cut.

(2) Twisting

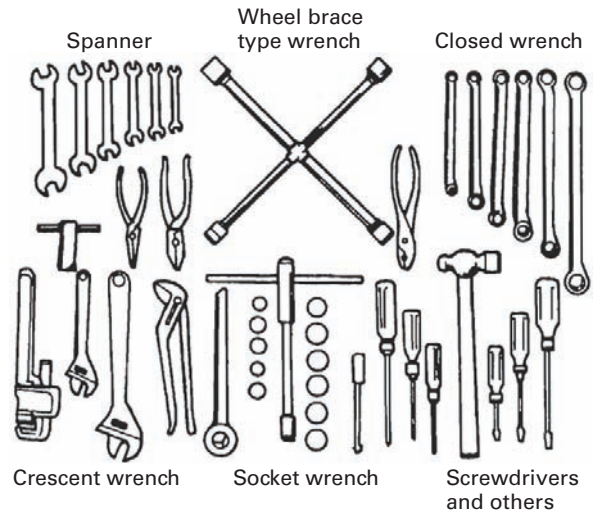
1) Spanners and wrenches

These are mainly used to tighten or loosen bolts and nuts. They are used frequently. There are spanners that are used to clamp the head of a bolt in a U-shaped opening part, ring spanners that are used by applying force to the whole area surrounding a bolt, and a wheel brace type wrench that covers the head of a bolt. A socket wrench is the same but it doesn't have the shaft a wheel brace type wrench has to cover a bolt. They come with attachments such as different size sockets, handles with a ratcheting mechanism, and hand-held shafts.

2) Screwdrivers

Screwdrivers are used for tightening and loosening screws. They have slotted (-) and crosshead (+), or Phillips, heads, and are also classified according to the type of handle they have. These include standard, stubby and feed-through handles.

■ Hand tools



(3) Gripping

1) Pliers

In addition to ordinary pliers used for bending and cutting wire and iron sheets, there are needle-nose pliers with a thin tip, circlip pliers, and linesman pliers that are handy for removing the coating of plastic wire and for attaching connectors.

(4) Cutting

1) Saws

In vehicle repair, a hand saw is used for cutting pillars. Although hand saws are being used less due to the increase in the use of air-powered cutting tools in recent years, a hand saw is useful when more delicate work is required.

2) Chisels

Rather than being used for cutting, in vehicle repair a chisel is used to remove spot welds on welded panels and for hammering out press lines.

3) Cutters

Although there are cutters used for cutting metal that have crosscut blades and straight blades, today they are hardly ever used in vehicle repair.

(5) Dedicated tools

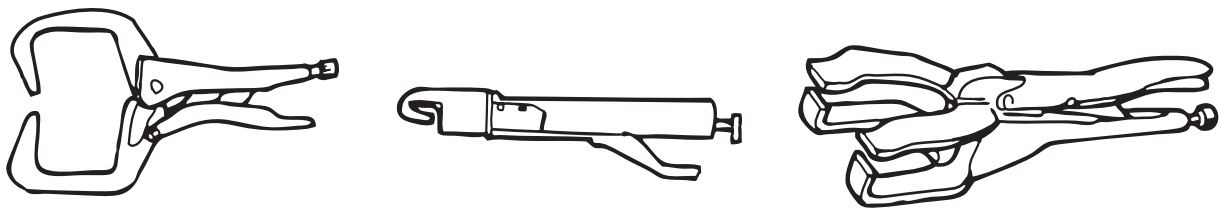
These tools are not general-purpose tools. They are used only in vehicle repair.

1) Clip removal tools

These come in a variety of shapes. There are those like a screwdriver with a flattened Y-shape tip.

2) Welding clamps

These are usually known by product name, but are also called vice grips. They are used to hold panels to be welded. There are various sets with a range of sizes and different shaped heads to suit different repair sites.

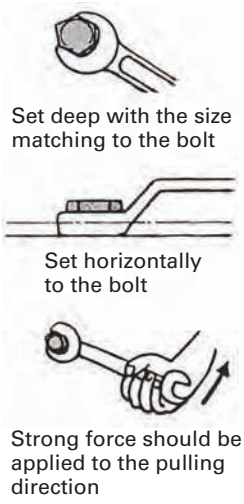
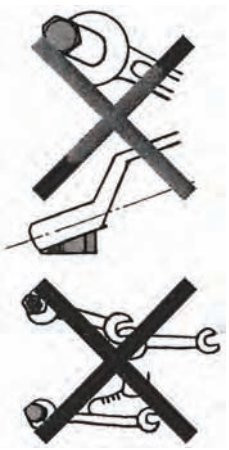


(6) How to handle hand tools

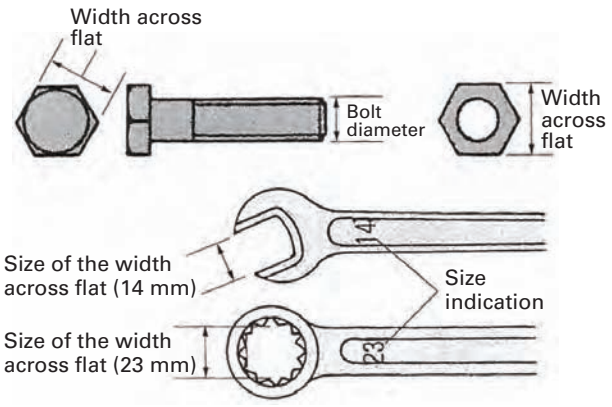
The basic principle of hand tools is to know what they are used for and not to use them for any other purpose. For example, you should not use a screwdriver to make a hole in sheetmetal or hit the head of a bolt with a spanner just to speed up the job.

The lengths of spanners and wrenches and the thickness of screwdriver shafts are designed to provide the appropriate amount of force for the various bolts and nuts. Consequently, if they are lengthened using a pipe or other tools or too much pressure is applied, not only the tool but also the bolt or nut you are working on could be damaged.

■ How to handle hand tools

Correct way to use	Wrong way to use
 Set deep with the size matching to the bolt Set horizontally to the bolt Strong force should be applied to the pulling direction	

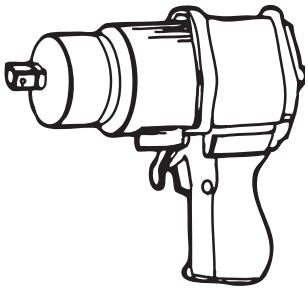
■ Bolt and nut width across flat



2. Power tools

Power tools driven by air or electricity are useful for reducing the amount of energy needed and are used to obtain a tidy finish.

(1) Removal and fitting tools

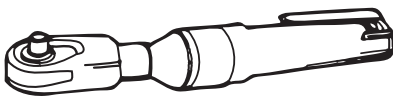


1) Impact wrench

An impact wrench tightens and fastens bolts while applying an impact blow. It uses a hexagonal chuck. The shank, where the bits are attached, comes in several sizes. The most commonly used sizes are half-inch (12.7 mm) shanks used for wheel nut wrenches and the 3/8-inch (9.5 mm) shank used for removing and fitting panels and parts.

2) Air ratchet

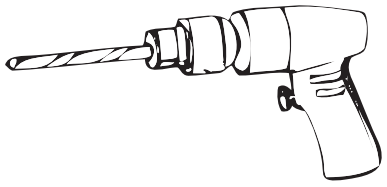
An air ratchet is used to quickly turn bolts in narrow places. It can be used with a socket wrench and bit.

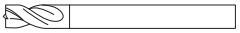


(2) Drilling and joggling tools

1) Air drill

An air drill is mainly used to grind down welds. There are also drills designed for spot welds that have adjustable depths.





2) Spot cutter

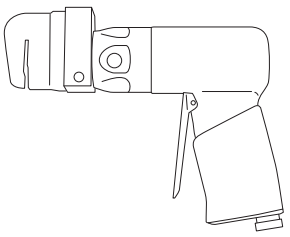
A spot cutter is used specifically for drilling a hole in spot welds without wearing the tip. The cutter is attached to a spot drill.

3) Punching tools

Punching tools are used for drilling holes in MIG plug welds. There are also manual punching tools.

4) Flanging tools

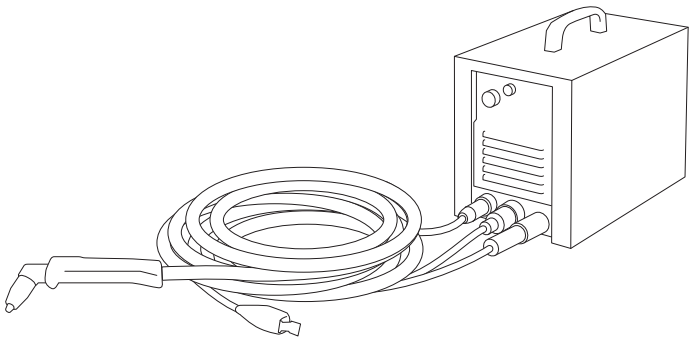
A flange tool is used to make a butt on a joint in a welded panel. Some types can also punch holes while some come with different shaped tips used for crowns and corners.



(3) Cutting equipment

1) Plasma cutter

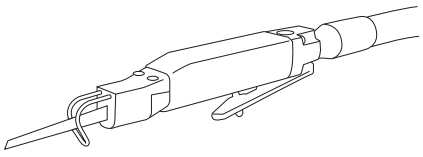
Using a plasma arc and air, the plasma cutter cuts even thick panels made of any type of material. It produces a clean finish on the cutting surface.



2) Air saw

This is an air-powered saw. The saw blade moves up and down, and there are low-speed and high-speed models.

The air chisel was the first air-powered cutting tool and was followed by rotary cutters and air nibblers. The most commonly used tool today is the air saw, which creates a clean cut.



3. Removal and fitting pointers

(1) Tires and wheels

When removing and fitting parts, refer to the service manual and body repair manual. Below is a guide to points requiring attention for various sites.

First, tires and wheels are often removed and fitted when repairing a vehicle.

Ride comfort and safety are impaired as a result of vibration caused by imbalance in tires and wheels due to some spots being heavy or light. A wheel has both static balance and dynamic balance. Special equipment (wheel balancer) is used to measure position and weight. A small weight is attached to the edge of the wheel to regulate balance, but if it comes off as a result of impact caused by a collision the wheel's balance will naturally be affected. Check carefully when removing or fitting tires or wheels and if it has come off the tire and wheel assembly will need to be balanced.

Because the wheel alignment is not the same for each wheel, once you have removed a wheel make sure you return it to the same place. To do this, when removing wheels mark them to show their location, for example, right front or left rear.

Checking tire pressure is one item to be checked before returning a vehicle to the owner.

When attaching or removing wheels and tires, check the torque and make sure they are not secured too tightly.

(2) Windshield glass

1) Attachment

The attachment of windshields and rear windows not only seals a cabinet but it is also used to retain vehicle strength.

The windshield is attached using either adhesive or weather stripping.

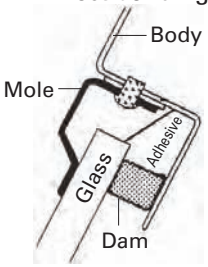
① Adhesive method

Glass attached using adhesive is attached by either direct bonding or flash mounts. The glass is attached to the body using adhesive for both methods, and in direct bonding the mole is attached using clips and in flash mounting the mole is buried in the adhesive. The adhesive method gives a vehicle more rigidity compared with the weather stripping method, but makes attachment/removal and replacement more difficult.

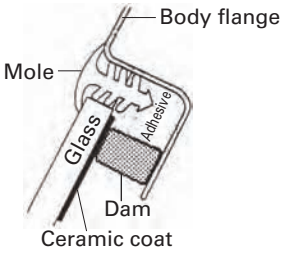
② Weather stripping

This is also known as the gasket method. The glass is fixed in place using H-shaped weather stripping and a non-drying sealant is filled in the space between the glass and body.

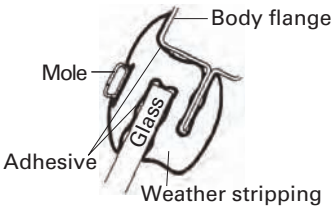
■ Direct bonding method



■ Flash mount method



■ Weather stripping method



2) Removal and fitting

① Removal

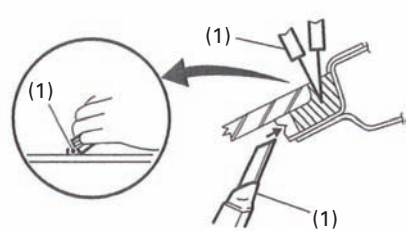
For windshields attached using adhesive, remove using either a glass knife or piano wire.

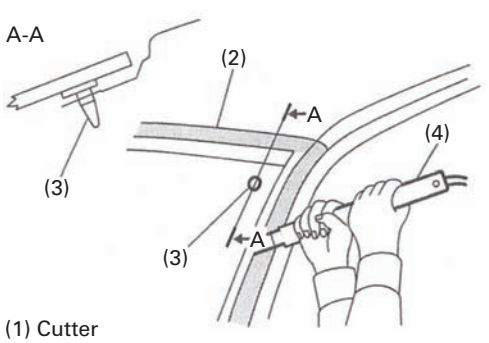
Hold the knife with the blade and glass at a right angle and cut out the adhesive sliding the blade along the glass. Start where the gap between the glass and body is the biggest and be sure not to twist the knife. Locating pins are attached to the corners of the glass so remove these using piano wire.

When using piano wire, make a hole in the adhesive using a drill or cutter, put the piano wire through and attach both ends to a short piece of wood. Pull on both ends of the piano wire and cut away the adhesive.

Do not cross the wire and do not pull hard against the edge of the glass. Be careful not to damage nearby parts.

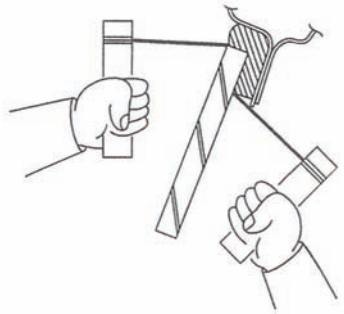
■ Removing with a knife





(1) Cutter
(2) Protection tape
(3) Locating pin
(4) Knife for windshield glass

■ Removing using the piano wire



② Fitting

Remove dirt from the surrounding area and using a cutter knife cut back the adhesive on the body to create a smooth surface around 2 mm (0.08 inch) thick. Be careful not to mark the body or painting surface.

Next, align the positions of the locating pins on the glass side and the holes on the body side and place the glass against the body. Adjust the position, and after clearance at each of the four corners has been evened, remove the glass and fit the rubber dam.

Align the molding mark with both upper edges of the glass and fit the molding from the upper corners to the center. Attach molding double-sided tape evenly to the side of the glass.

Using a sponge, coat primer on the adhesive surface on the glass side and body side. At this point, because primer that gets onto the body painting surface or the interior trim is hard to remove, cover the surrounding area. Let the primer dry for around 10 minutes. Do not touch the primed surface.

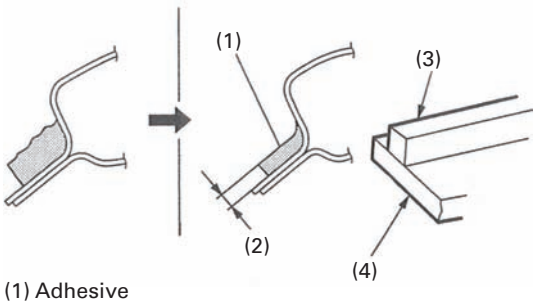
Apply adhesive to the edges of the glass, then using a rubber suction cup insert the rocket pins on the body side and attach the glass. Push lightly and make sure it is fixed in place. Even out any excess adhesive with an applicator.

When installation is completed, leave the vehicle for about 24 hours.

Follow the adhesive manufacturer's guidelines for the minimum drying time and the length of time the vehicle should be left before it is driven. Once the adhesive has dried, pour water over the outside surface to check whether there are any leaks.

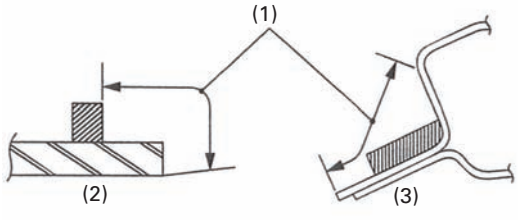
When returning the vehicle to the owner, tell the owner not to subject the vehicle to any hard knocks for at least three days.

■ Cut back the adhesive



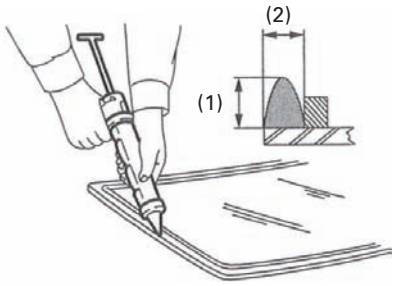
(1) Adhesive
(2) 2 mm (0.08 in)
(3) Rubber dam
(4) Glass

■ Applying the primer



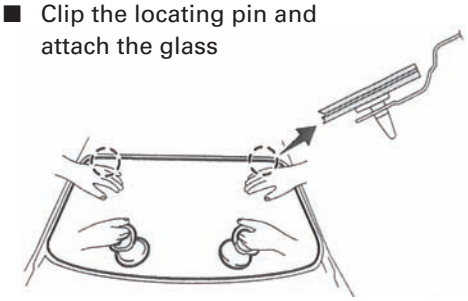
(1) Application surface of the primer
(2) Glass side
(3) Body side

■ Applying adhesive



(1) 9 - 12 mm (0.35 - 0.47 in)
(2) 8 mm (0.31 in)

■ Clip the locating pin and attach the glass



4. Electrical components, wire harness

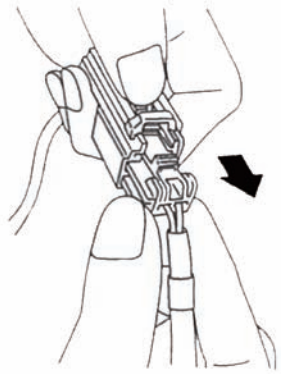
Vehicles are fitted with many electrically operated parts. They are covered with elaborate systems of wiring (wire harness) used to supply electricity and to control the parts.

When attaching/removing electrical parts, make sure you take off the negative terminal on the battery beforehand. If removing parts with a memory function like the audio unit and control unit, record the memory contents before taking off the negative terminal. If you neglect to do this all contents in the memory will be erased.

When attaching/removing and replacing panels and parts during vehicle repair, wiring often has to be disconnected. It is for this reason that connectors are fitted to sites with wiring to enable disconnection.

Most connectors are made of plastic, so handle them with care as they can be damaged if handled too roughly. To ensure smooth re-connection, when disconnecting wire attach a sticker or label so that you can identify where it is from.

■ Connector



5. Air bags

Air bags are adopted to improve passenger and driver safety. They are designed so that they will deploy upon detecting impact. Since pyrotechnic devices are used to inflate air bags, they must be handled carefully.

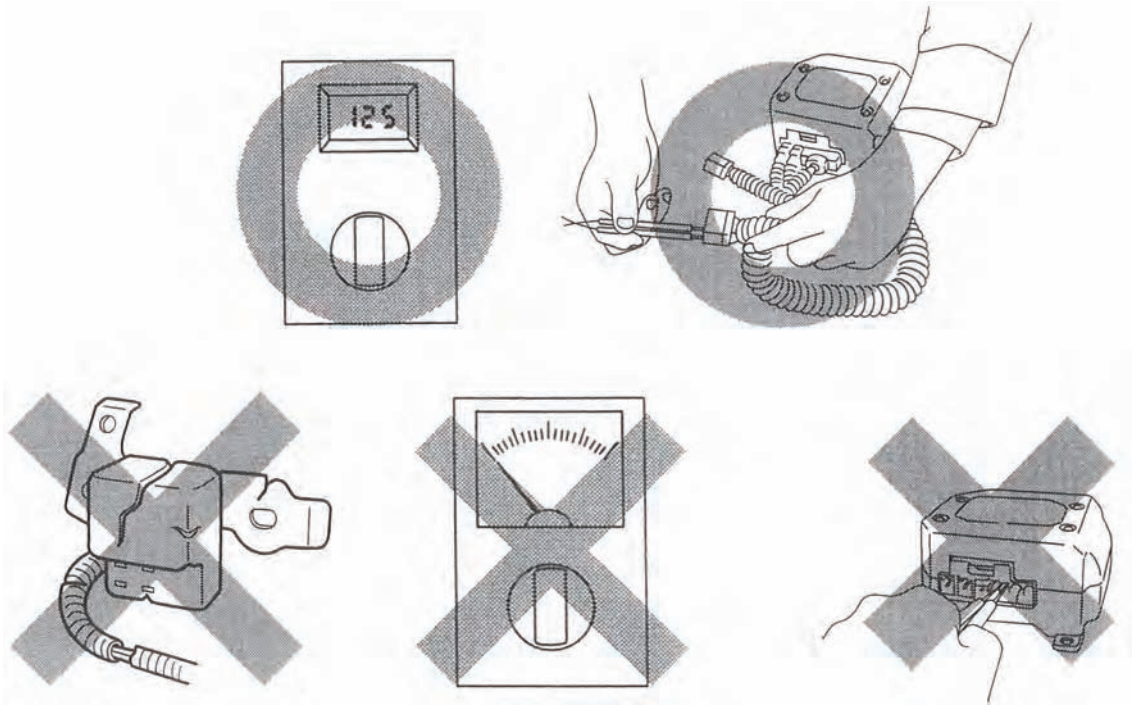
The driver's air bag is stored in the steering wheel pad and the front passenger air bag is stored in the dashboard.

If there is damage or deformation occurs in the sensors, air bag module, air bag control unit, pretensioner, and harness replace with a new product. Use a digital circuit tester when checking air bags. Do not use an analog circuit tester, as the small amount of current inside could deploy an air bag.

Disconnect the air bag connector or remove the battery since an air bag may deploy unexpectedly.

Removing and installing air bags must be done with the utmost care. Refer to the service manual when doing this and also if they are to be discarded.

■ Follow the manual when working on air bags



6. Types of grease

The radiator and air conditioning unit fitted at the front of the engine bay are often involved when repairing a vehicle. These parts have to be removed when they are damaged and also when the radiator panel is replaced. Always top up the radiator, but if the level of water drops due to radiator damage, it must be filled with water and the prescribed ratio of coolant.

Recover and fill air conditioner gas using special equipment. Dispose of the gas following recycling regulations.

Other work will require the removal and filling of other solutions, such as power steering fluid, brake fluid, engine oil, and transmission oil. Since these are all vital for vehicle safety, you must follow the guidelines set out in the service manual.

■ Filling the refrigerant

Chapter 9 Repair of the underframe

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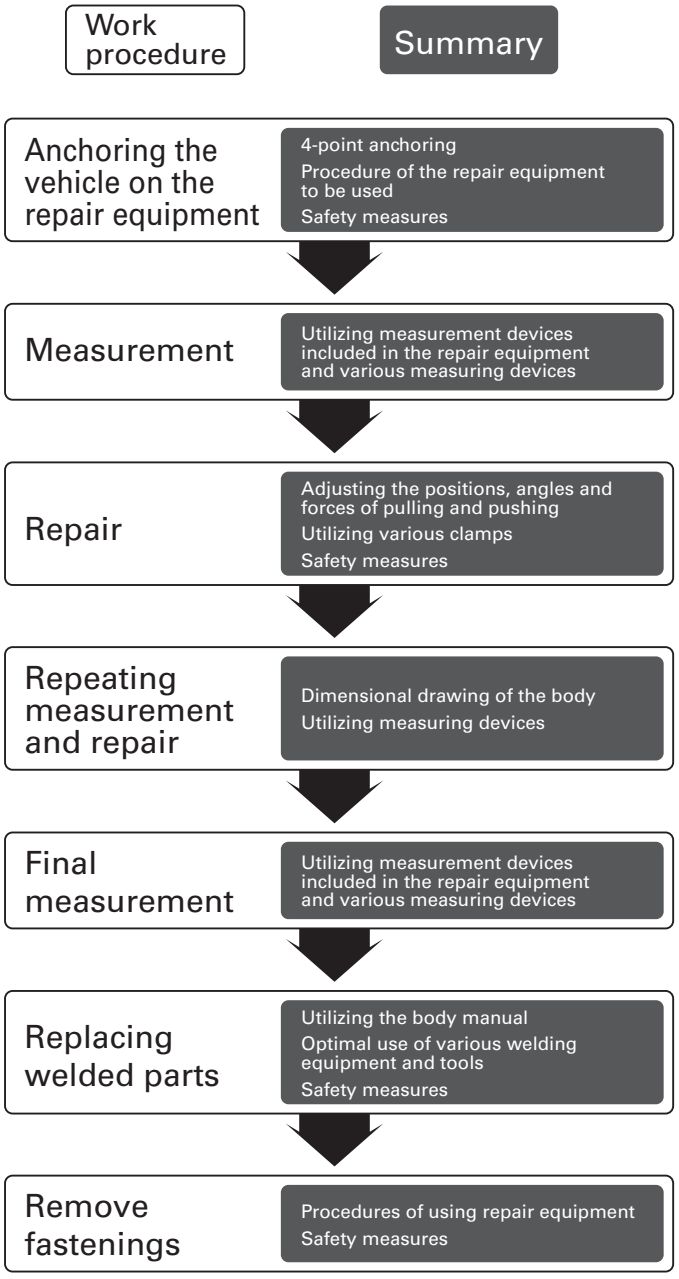
1. Order for inner panel and underframe repairs

Body adjustment and alignment equipment is used when repairing damage to the underframe.

The basic order when using this equipment is to fix (set), measure, repair, measure, replace welded parts, and unfasten (reset).

The work returns the vehicle to its original dimensions. By repeated repairs and measurements, the original dimensions of the frame are gradually restored. Leave structural parts that are scheduled to be replaced on until you have obtained the measurements you need.

When the dimensions are correct, unfasten the vehicle from the adjustment and alignment equipment after the welded panels have been replaced.


Work procedure
Summary
Anchoring the vehicle on the repair equipment
4-point anchoring
Procedure of the repair equipment to be used
Safety measures
Measurement
Utilizing measurement devices included in the repair equipment and various measuring devices
Repair
Adjusting the positions, angles and forces of pulling and pushing
Utilizing various clamps
Safety measures
Repeating measurement and repair
Dimensional drawing of the body
Utilizing measuring devices
Final measurement
Utilizing measurement devices included in the repair equipment and various measuring devices
Replacing welded parts
Utilizing the body manual
Optimal use of various welding equipment and tools
Safety measures
Remove fastenings
Procedures of using repair equipment
Safety measures

2. Body adjustment and alignment equipment

(1) Development history

Repairing a vehicle body deformed in an accident most likely started at the same time as the invention of the automobile. In those days, repairers inherited repair techniques used for horse-pulled carriages. For a long time, basic body construction remained virtually the same as that used for carriages, except that wood had been replaced by iron.

Huge changes appeared in body construction with the birth of the unitized body. There was a significant increase in vehicles with the unitized body in Europe after the Second World War. That was when special repair tools for this type of body and present-day body adjustment and alignment equipment appeared. Little was written about this so details remain unclear.

We do know, however, that the forerunner of today's jig type equipment was developed in France in the 1950s. It is thought that the owner of a car repair workshop developed it by making modifications in the course of carrying out daily repair work.

The floor-type Blackhawk Korek system was introduced to Japan from the United States in the early 1970s. Meanwhile, domestically produced floor-type auto poles appeared one after the other. This type of equipment most likely became widely adopted due to demand for more efficient repairs accompanying the sudden rise in vehicle ownership.

This was followed by an increase in equipment imported from Europe and elsewhere, as well as the development of improved models in Japan. By the 1980s they had been introduced to a great many vehicle repair workshops. This is also when there was an increase in equipment that was solely used for anchoring vehicles, as well as a variety of related equipment such as measuring equipment.

Today, most main types of overseas equipment are imported to Japan, and along with domestically made equipment both are used taking advantage of the benefits particular to each system.

(2) Types and characteristics

1) Criteria for body adjustment and alignment equipment

Equipment must use huge force to pull the deformed underframe while the vehicle is braced so that it won't move, and must be able to measure deviation from standard positions with millimeter accuracy. This equipment serves three main purposes.

Although some have a single function, the systems were originally designed to have these three functions.

There are three main different types of system: floor, bench and platform (drive-on).

① Pulling equipment

This is used to pull and push parts of the body freely with a specified force.

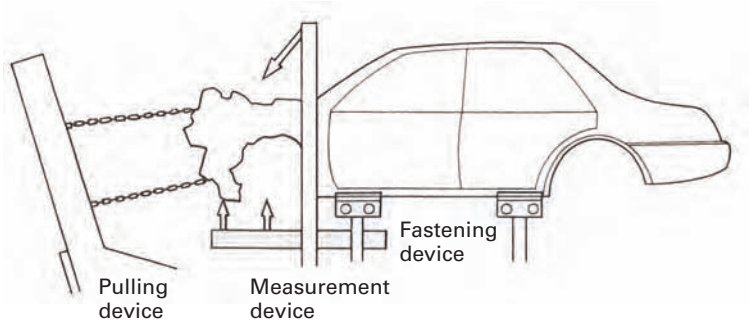
② Anchoring equipment

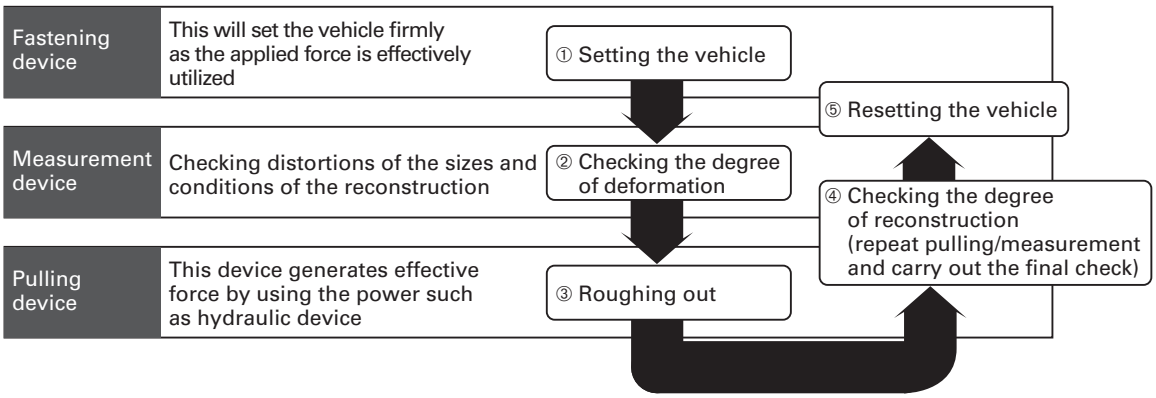
This stops the body from moving from its position when force is applied. What is more, vehicles can be anchored and released quickly.

③ Measuring equipment

This equipment gives accurate measurements and comparisons without needing plenty of experience.

■Three requirements




Fastening device
This will set the vehicle firmly as the applied force is effectively utilized
① Setting the vehicle
⑤ Resetting the vehicle
Measurement device
Checking distortions of the sizes and conditions of the reconstruction
② Checking the degree of deformation
④ Checking the degree of reconstruction (repeat pulling/measurement and carry out the final check)
Pulling device
This device generates effective force by using the power such as hydraulic device
③ Roughing out

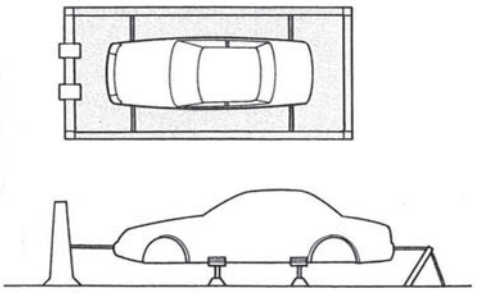
2) Floor systems

Floor systems anchor pulling equipment and anchoring equipment to rails or anchors embedded in the floor.

They allow independent use of individual systems and allow the easy anchoring of single sections. They don't take up much space, as when not use the various parts can be stored away. However, the rails or anchors remain in the floor.

Rails are made of aluminum as well as steel, and some systems use a rubber cover to obtain a flat surface.

The individual parts can be used flexibly in combination with other adjustment and alignment systems and equipment.



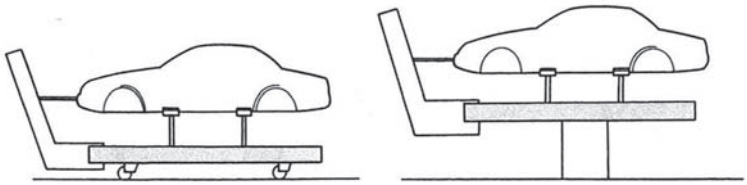
3) Bench-type systems

These systems are based on taking measurements using a jig.

A jig is mainly used to show the correct positions of major points on the underbody. There are dedicated systems that require special attachments for each vehicle model, and there are universal systems that can be used for any model by relying on a frame chart. Many of these systems are European.

The platform used to set the jig is a jig bench, and pulling systems and setting systems are also set using the bench. The bench itself is portable. However, for reasons of convenience the system is often used in combination with a hoist, which means it occupies its own space. Lifts improve efficiency as the height of the vehicle can be freely adjusted during the repair process.

Since all that is required is to pull in the direction of the dimensions and positions showed three-dimensionally by the jig, work is fast and even the inexperienced can use this system. However, it does take time to set up the jig.



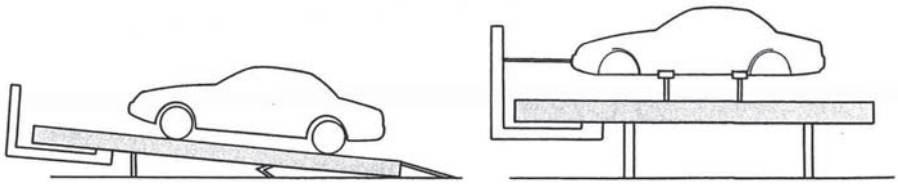
Portable bench and bench placed on a hoist.

4) Platform system

This is also known as a drive-on system because the vehicle is driven on to the work platform.

The pulling system and anchoring system are integrated, and setting up requires a certain amount of space. Many of these systems are made in North America.

To set up, the platform is tilted so that the end is at floor height, and the vehicle is driven or pulled by a chain onto the platform. Because the vehicle is around one meter off the ground it makes working on the suspension easy.



Platform tilts and moves up and down

5) Other systems

Other systems are basically variations of the floor, jig bench and platform systems.

Some platform systems have a scaffold (birdcage) that encloses the entire vehicle. These systems enable pulling from many directions.

Some systems combine a jig bench with a platform or floor system.

Simple floor systems with only anchoring parts can be used in combination with separate measuring and pulling systems. The advantage of this system is the low initial cost.

6) Related equipment

In addition to the functions of anchoring, measuring and pulling, body adjustment and alignment systems come with a variety of other related devices and equipment

Clamps are used to grip panels, and there is a wide variety of shapes owing to the variety of damage sites and conditions. There are underbody clamps (generally used at the front and rear right and left sides of the side sills) that anchor the body and panel clamps used on damaged sites and for additional anchoring.

Hydraulic rams have been mentioned earlier in the section on repairing outer panels. A hydraulic ram is a must because it can be used universally, from a tower used for making repairs through to a power unit that pulls chains and a tool that does auxiliary pushing and pulling using attachments.

There are also chain pullers (chain blocks) that can be used to pull. These are used when pulling systems are too strong and when repairing minor damage. They can also be used for auxiliary anchoring.

Measuring systems are part of body use of attachments systems and are mainly used on the underbody. There is also the tram gauge, which is used to measure lengths of certain parts.

More detail on various devices and instruments is included in a later chapter.

3. Anchoring the body

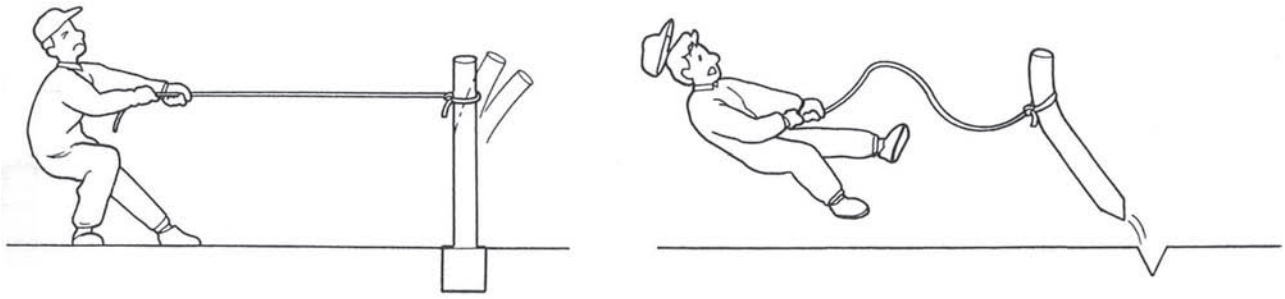
(1) The role of anchoring

Pulling force cannot be used effectively unless the vehicle body is firmly anchored.

The anchored parts receive the same force used in the pulling process. If a low strength area is anchored when strong force is applied, the anchored part will either deform or disintegrate.

Even for strong areas the right site must be chosen, otherwise moment caused upon the application of force may result in the application of force in a different direction. Not only will this slow down repair work, but it will cause additional deformation.

■ Role of anchoring



Adequate force cannot be applied without firm anchoring.

(2) Basic anchoring methods

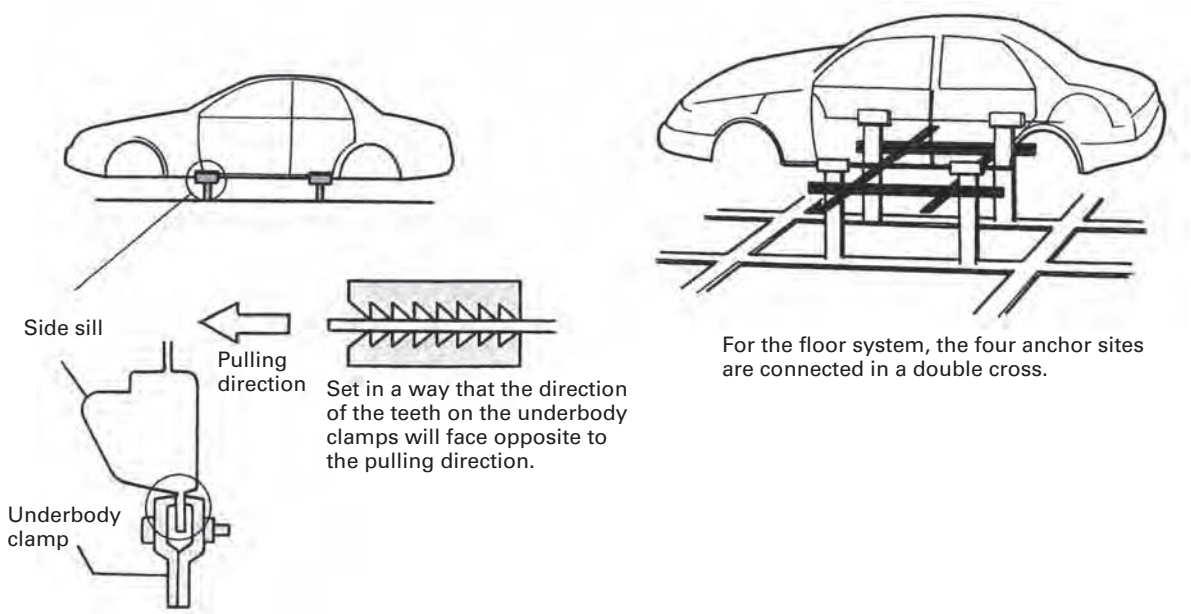
Basic anchoring is combined with setting up the body alignment system. Normally, the flanges under the side sills are anchored to the equipment using underbody clamps or special clamps for particular car models. The body is anchored in four sites, front back left and right.

The four clamps must be connected so that strong force is not applied to one site only. Though vehicle models vary, because with the floor system the anchor sites are apart from one another the underbody clamps are connected with metal tubes shaped like a hanging rack. They are not connected in bench or platform systems because the anchored sites and the bench are close.

If there are no flanges under the side sills, create anchorage by welding on a thin panel or use a special anchor adapter available for each model. In cases where the frame is separate, like for a truck, the frame and body are anchored separately.

Anchoring is also difficult if there is damage to the side of the body. Anchor the undamaged side as normal and add anchor points at the front and rear to disperse the pulling force.

■ Basic anchoring

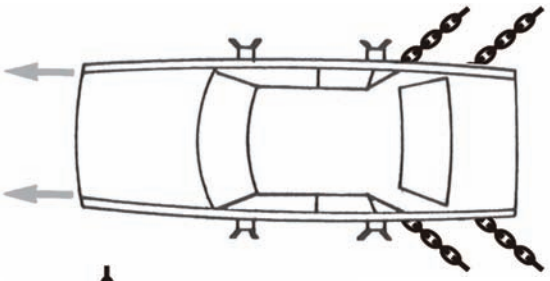

Side sill
Pulling direction
Underbody clamp
Set in a way that the direction of the teeth on the underbody clamps will face opposite to the pulling direction.
For the floor system, the four anchor sites are connected in a double cross.

(3) Supplementary anchoring

Depending on the direction of the pulling force, adding supplementary anchoring can make repair easier by making effective use of the pulling force. Supplementary anchoring is mainly required in the following instances.

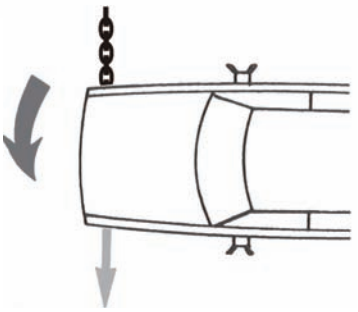
1) To reinforce basic anchoring

When chains are used for anchoring, the direction of the pulling force can cause the chains to slacken. In such instances, add anchors in the opposite direction.



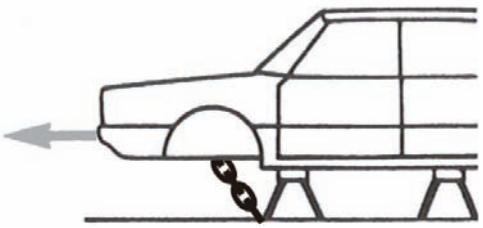
2) To counter moment

Not all pulling is done on the center of the body. Adding anchors in the direction of the moment caused by pulling and the opposite direction of the moment will prevent further deformation.



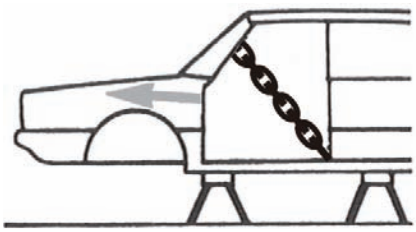
3) To prevent excessive pulling

Pulling force travels to a fixed point and does not affect any points past the fixed point. For example, if you want to pull on the front half of the front frame, anchors should be added immediately behind the area you want to align. Adding anchors to the opposite side when pulling from the side makes effective use of the force.



4) To protect opening parts

The upper part of the body is not anchored. Consequently, when strong force is applied it can have an effect as far as the front pillars. Therefore, connecting the top of the front pillar and the upper surface of the side sill will prevent deformation in the door. When pulling near the trunk, add a heavy rod to the part where the trunk opens.



4. Setting adjustment and alignment equipment

(1) Setting floor-type adjustment and alignment equipment

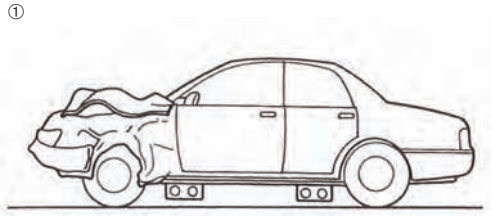
Assemble the anchoring system over the floor rails and anchors and set the damaged vehicle. Although this will vary slightly from model to model, first move the vehicle to the prescribed position. If the vehicle cannot be driven, use a trailer or tow truck. If using manpower, use three or more people and designate one person to monitor the surrounding area. If the steering wheel or brake can be used move the vehicle after checking them.

Place damaged parts in a wide corridor, transport the vehicle to the prescribed position of the rails and anchors and first attach underbody clamps to the underneath of the side sills. Sites near the jack points listed in the service manual are suitable locations for the clamps. Then install the piping that connects the front back and right and left. Leave the anchor bolts in place.

Next, assemble the anchoring system in line with the underbody clamps and fix it to the rails. If you are able, raise the vehicle using a jack or the hoist that comes with the adjustment and alignment equipment. When using a jack, set up a rigid rack by jacking the front and back separately. A rigid rack can be omitted if work underneath the body is not necessary.

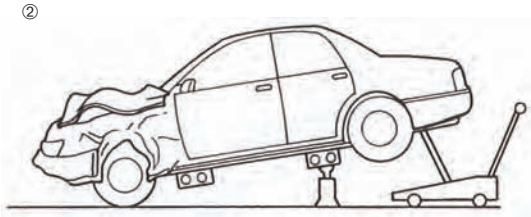
Adjust the positions of the underbody clamps and the anchoring system, and when it is firmly in place tighten the connecting pipes. The setting is now completed. For the fastening type that uses chains, support the body by placing rigid racks against the right and left connecting pipes. Then anchor the vehicle by attaching at least four chains to the front and back on both sides of the vehicle. If the vehicle is severely damaged, it is a good idea to add chains in the pulling direction and in the opposite direction.

①



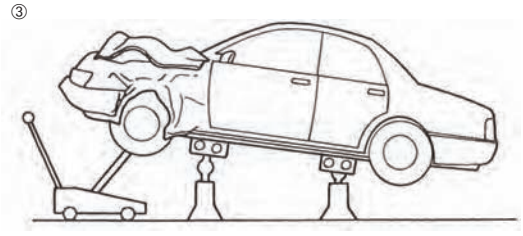
Attach underbody clamps to the four sites of the side sill flanges

②



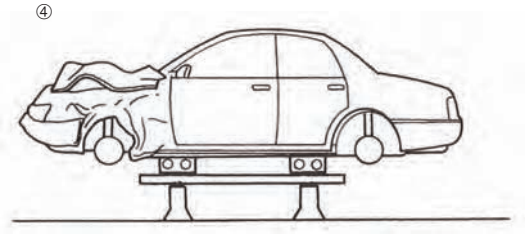
Lift the rear side using a jack and set the anchor stand

③



Place the rear side on the anchor stand and set the anchor stand in the same way for the front side

④



Once both front and back are on the anchor stand, join the connection pipes and fasten the vehicle using chains, wedges and bolts

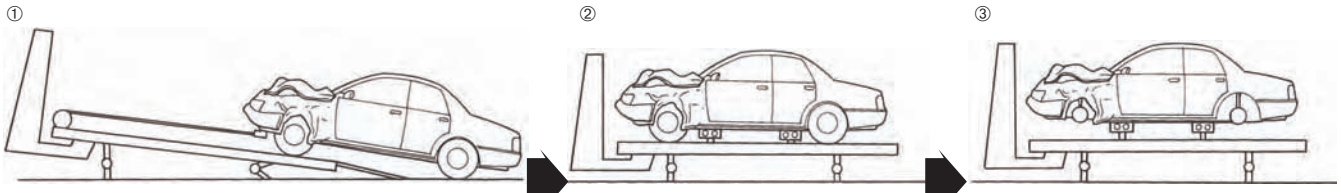
* If the hoist is installed at the center of the floor type repair equipment, those operations ② and ③ can be completed at once

(2) Setting platform-type adjustment and alignment equipment

After moving the vehicle near the equipment, either tilt or lower the platform and either drive the car onto the platform or use a winch.

Return the platform to its proper position, raise the vehicle on the platform using the jacks that are originally included and attach the underbody clamps and anchor stands. Take down the jacks and fix the anchors to the base. Setting is now completed.

For vehicles with damaged tires that can't be driven, use a special support with wheels.



Place the damaged car on the tilted platform by either driving the car or using a winch

Set the fastening clamps and fasten the car on the platform

Remove the wheels

(3) Setting bench-type adjustment and alignment equipment

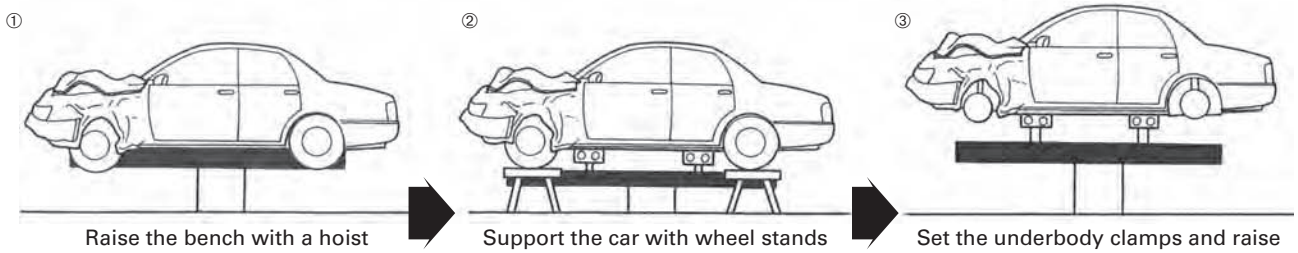
The methods of setting up a bench-type system vary depending on whether there is a hoist and on the type of hoist.

If there is no hoist, place the damaged vehicle on a support stand. After attaching the underbody clamps, put the bench underneath the vehicle, raise the bench with a garage jack and attach the anchor stands to the bench. Raise the bench higher and take down the vehicle stand.

If there is a forklift or similar type of hoist that can raise the vehicle from the side, a stand is not needed as the vehicle can be placed directly on the bench. Raising the vehicle with a hoist with four or three columns makes this task easy. Since the bench has casters, after setting up you can move it to a space where you can work on the vehicle.

If the bench body is attached to a hoist, raise the vehicle once on the bench, support the vehicle with a special stand and then attach the underbody clamps. Although you can't move it once it has been set up, the vehicle can be raised and lowered while working.

Benches that serve as measuring systems can also be used in conjunction with floor-type and platform-type equipment. In such cases, the vehicle is anchored to the bench, the vehicle to the adjustment and alignment equipment and the equipment to the bench.



Raise the bench with a hoist and lift the damaged car

Support the car with wheel stands or a rigid rack that can be used from the gaps of the bench, and lower the bench

Set the underbody clamps and raise the bench again and remove the stands

(4) Anchoring the damaged vehicle horizontally

Different systems have various tricks to loading vehicles that make the work more efficient. It is important that you grasp these various features.

For almost all models it is important that the damaged vehicle is positioned horizontally. To be accurate the axis of the bench or platform should be parallel with the vehicle. With floor systems, the vehicle should be positioned parallel to the baseline of the measuring system, or if the floor is level the vehicle should be anchored parallel to the floor.

5. Measuring the body

(1) The purpose of measuring

The body is measured to determine how misaligned the various parts of the deformed body are.

1) Length

The simplest measurement is to compare the length. For example, if the left fender is shorter than the right front fender, the left side has been pushed in.

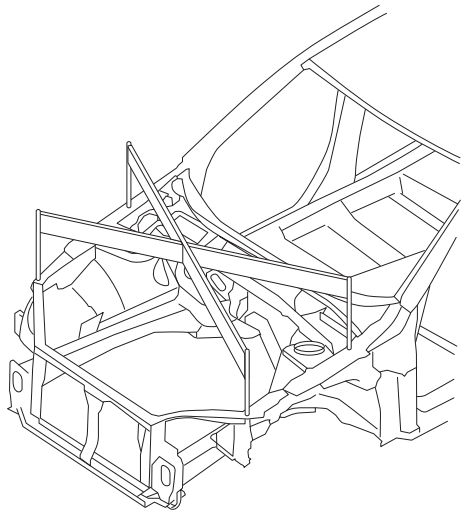
However, this is not an accurate assessment. This is because it is possible that the right side has stretched.

2) Diagonal measurements

Another way to compare measurements is to compare the diagonal measurements. The diagonals of the symmetrical quadrangles are the same. A vehicle body has many symmetrical parts, and this makes it possible to see deviation. Use a rod or something similar to measure the length of one of the diagonals and then use it to measure the other diagonal. If the lengths are the same the vehicle is normal, but if the dimensions are not the same there is deviation.

However, this only tells you the positional relationships of the four corners of the quadrangle and nothing about the panels in the middle. Also, since the body is three-dimensional, deviation occurs not only at the right and left of the front and back, but it also occurs above and below. Determining deviation based only on two-dimensional diagonals has its limitations.

■ Compare the opposing corners



3) Numeric conversion

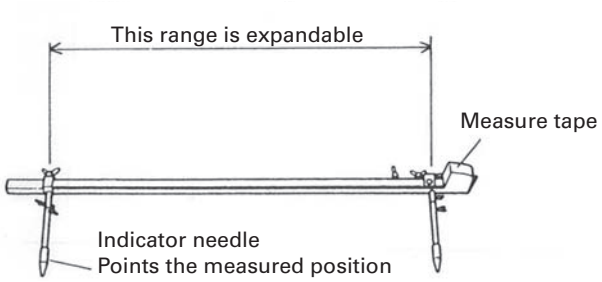
To grasp an accurate picture of the state of the vehicle lengths need to be substituted with numbers and interpreted. This is the task of measuring. Taking measurements will, for example, tell you that the upper surface of the front fender is 800 mm on the right and 780 mm on the left. However, this information is not enough. You must refer to the body manual to check the original dimensions. When you do this you find that the correct length is 805 mm. This tells you immediately that both lengths are wrong.

(2) Types of measuring devices and characteristics

The tram gauge and centering gauge are examples of universal measuring instruments.

1) Tram gauge

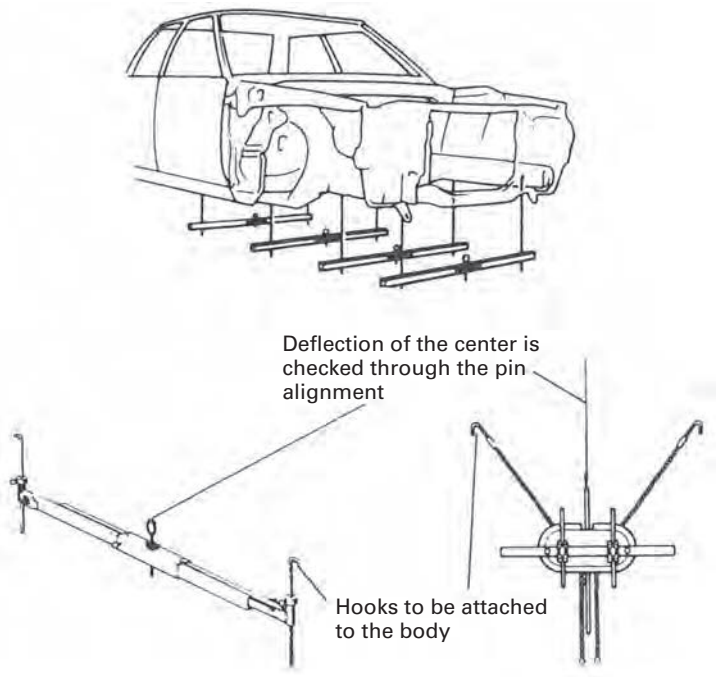
The length of the tram gauge is adjustable, and there is an indicator needle on the ends of each of the rods that can also be secured. The rods have a measuring tape and weights, and gauges from which the figures of the dimension between the two indicator needles can be read directly are most common. A tram gauge is useful for measuring the distance between two points on the body and it is also easy to handle. It is indispensable in body repair work.



2) Centering gauge

When suspended at the symmetrical points of the underbody it will automatically show the body's center line. By looking through a pin from one end you will see the deflection of the body. It takes a little time to learn how to look through the pin.

Other gauges that are suspended under the underbody include those that use a plate to measure the distance using laser beams. The centering does not provide figures, it only allows you to check alignment.



3) Adjustment and alignment equipment and measuring systems

Although jigs are often used in systems that combine measuring systems, there is a variety of other systems that are also used.

These include measuring using laser beams, and the use of computers to read data on the positions of indicators set under the underbody that can make real-time comparisons of these measurements and the correct dimensions.

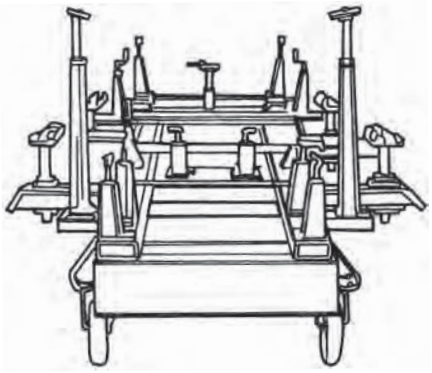
4) Jigs

A jig is a tool used for aligning parts. Jigs that are used in alignment systems show the normal positions of major body sites and parts. There are universal jigs and dedicated jigs

① Dedicated jig

A dedicated jig uses attachments designed for a specific model. They can also be used to hold the position of a new panel for placement and welding.

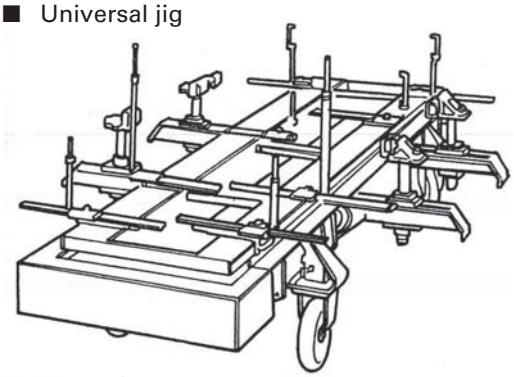
■ Dedicated jig



② Universal jig

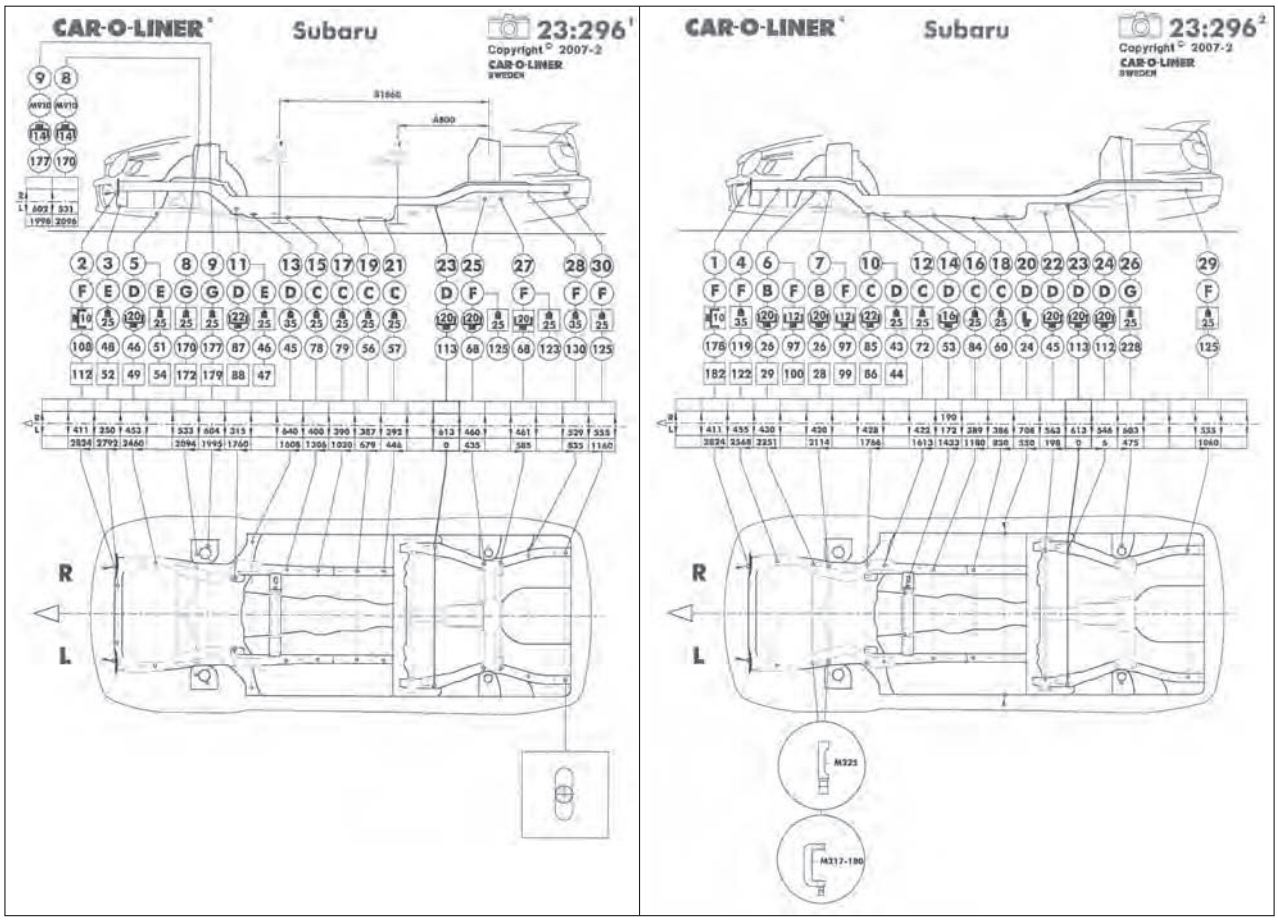
A universal jig can be used for many models by altering the way in which the provided jigs are assembled. The jigs are assembled by following the directions according to the body charts prepared for each model made by the manufacturer by taking actual measurements.

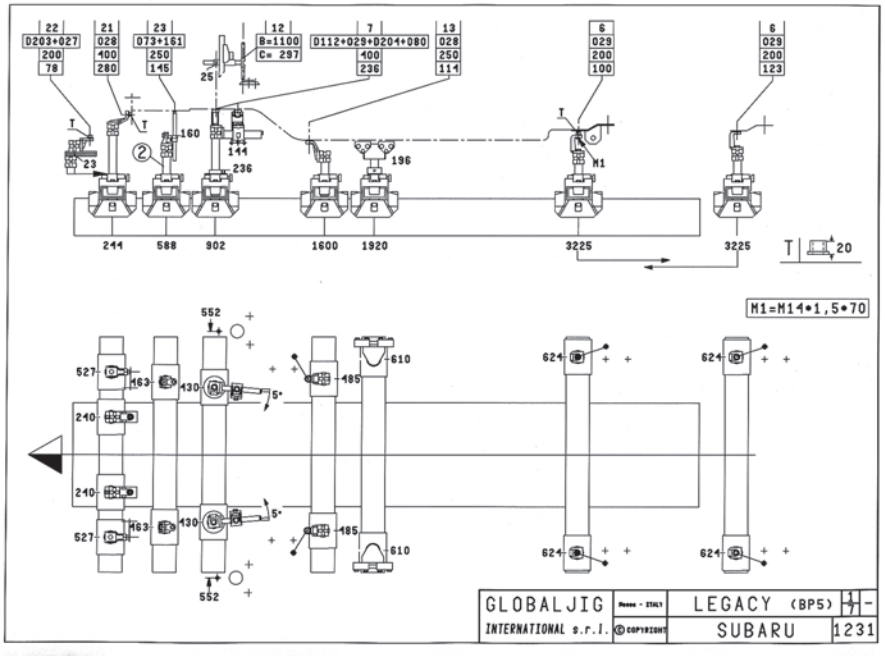
■ Universal jig



■ Body charts

Each universal jig system has its own set of body charts.

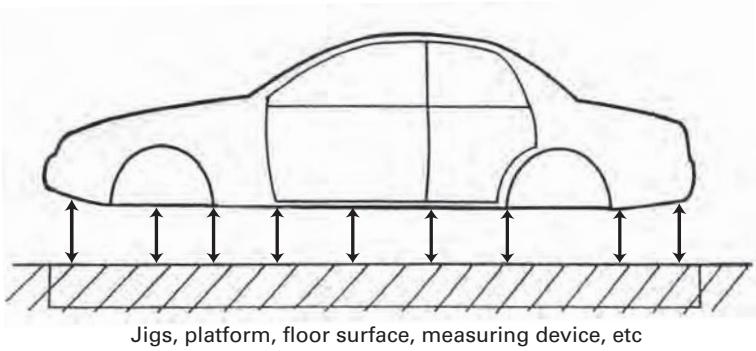




③ The principle behind a measurement plane

A plane is made at a set distance parallel to the body. It is possible to show the correct positions on the body using positions on this plane and this distance between the plane and the various areas on the body. As a plane, it doesn't have to be a plate-like surface with no gaps. A virtual plane is also acceptable. This is the basic principle behind jig-type measuring systems. Apart from ordinary jigs, there are also systems that extend arms from the frame to create a virtual plane and have attachments provided with measuring tapes.
Body dimension charts show the dimensions of a projected plane.

■ Measurements using a virtual plane



(3) How to read body charts

1) Body dimension charts

Body dimension charts show the true dimensions of new vehicles and are used for vehicle alignment. They are included in body manuals for each model.
Because with a unitized body the engine and suspension are directly attached to the body, their layout has a bearing on traveling performance and safety. For example, if the position of strut mounts is incorrect, the wheel alignment will be out, the vehicle won't travel straight, and the tires will suffer from abnormal abrasion.
If you have a body dimension chart you can proceed with body repairs even if the new panels haven't arrived.

2) Linear distance measurements and plane projection measurements

In Subaru body manuals, the underbody is shown by plane projection measurements and the upper body is shown using linear distance measurements.

① Linear distance measurements

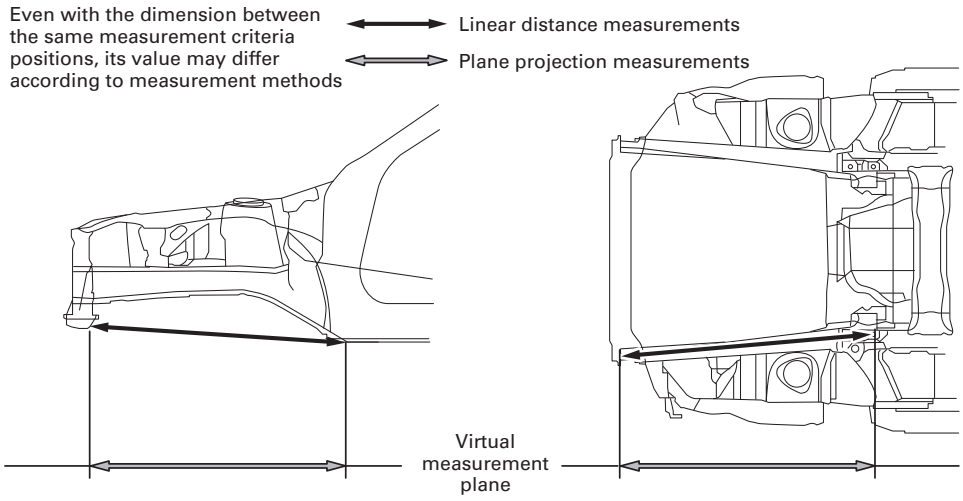
Linear distance measurements are taken by measuring the direct distance between two measurement points (vehicle reference points).
They are easy to understand because they can be measured directly using a calibrated tram gauge. However, it's often not possible to measure the inside of the engine room if the engine is there.

② **Plane projection measurements**

Plane projection measurements are obtained by establishing a virtual plane parallel to the body, and take measurements from an image of the body projected onto the plane. In other words, it takes planar measurements that do not take account of differences in height and width.

This is almost impossible to do with an ordinary tram gauge or measuring tape. These measurements are useful when using a set body and alignment and measuring equipment that have a parallel measuring plane (or lines). A cord with an attached weight is hung from the measurement points, and the distance between the places where the weights come in contact with the measurement plane is measured. This is why some systems (and measurement systems) come with indicator needles. Using this method it is possible to get the required measurements even if there are obstacles, such as the engine, suspension, and parts, in the way of taking a linear distance measurement between two points.

■ Linear distance measurements and plane projection measurements


Even with the dimension between the same measurement criteria positions, its value may differ according to measurement methods
Linear distance measurements
Plane projection measurements
Virtual measurement plane
In parallel with the central line of the body

3) Obtaining accurate measurements

Most of the body is symmetrical, but there are some areas that are asymmetrical. Although it is difficult to know right from left in the underbody, basically these are described from the point of view of looking down on the vehicle from above. Consequently, when taking measurements under a vehicle be aware that right and left are reversed.

Figures will also be incorrect if linear distance measurements and plane projection measurements are confused. When measuring the same place it is often shorter to take plane projection measurements rather than linear distance measurements.

Since a vehicle's reference points are surprisingly hard to find, check using diagrams in the body manual. Measure from the center of a hole.

6. Body alignment

(1) Accident entry and pulling

It is often said that in order to repair a damaged body all you have to do is apply the same amount of force in the opposite direction to the impact that occurred. In fact, however, it is difficult to accurately determine the amount of force and direction. Even if it were possible, the momentary force of an accident and the slower task of pulling are not the same. Also, body panels damaged as a result of the impact may already have a different strength compared with the original body as a result of work hardening.

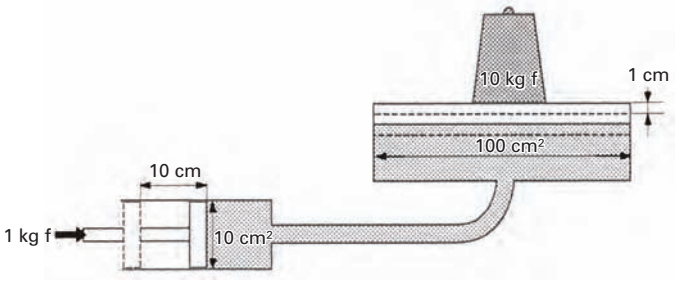
(2) Pulling systems and characteristics

1) Principles of hydraulic systems

Hydraulic systems are indispensable when repairing a vehicle body.

Pascal's principle applies to hydraulics. Namely, if there is a piston with a sectional area of 10 cm^2, and 1 kgf (9.81 N) of force is applied to oil (fluid) inside a device, a separate piston with a sectional area of 100 cm^2 connected by the same fluid will move with a force of 10 kgf (98.1b N). If the size ratio of the piston on the input side and the piston on the output side is altered, the same force can be increased infinitely. However, the strokes will decrease correspondingly.

■ Pascal's principle



if 1 kg f (9.81 N) of force is applied using a piston with the sectional area of 10 cm^2, since the force will be applied equally to the whole liquid, the piston with the sectional area of 10 times bigger, 100 cm^2 will have the force of 1kg f x 10. In other words, the ratio between the force and sectional area is always the same

2) Hydraulic mechanism

In a simple hydraulic device used in body repair, the fluid to which pressure has been added by manually pushing a pump amplifies its force in a piston in a hydraulic ram. A hydraulic ram can be used for a variety of purposes, centering on pistons, by fitting new pipes and changing the attachments on the tip.

Its many uses include widening a spot that has been pushed in, raising an area that is sagging and stretching a panel that is compressed. But because of its force it is often used to repair sites on the frame, such as frames (members) and pillars.

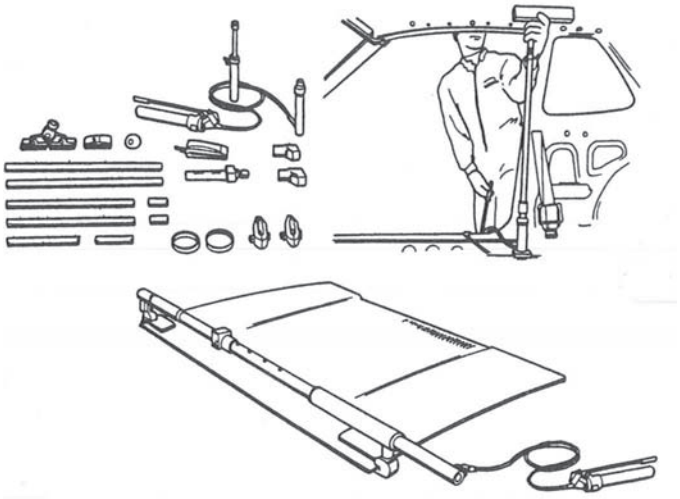
When a hydraulic ram is about to release a large amount of force the stroke (ram) displacement decreases. As a result, there is a limit to how much manual pumps can be used when the pushing distance is long and you want to increase force.

An air pump driven by compressed air is used in such cases. With the flick of a switch you can get the required force and stroke.

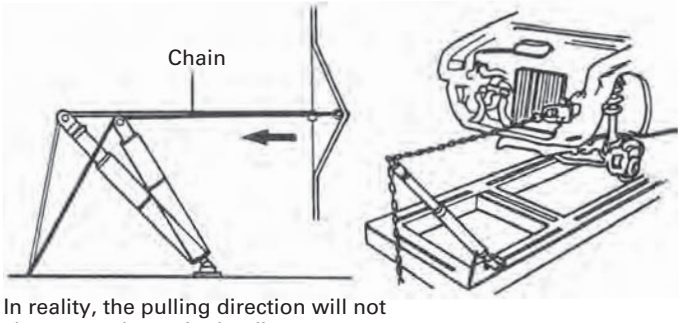
Most hoists and jacks used for repairing vehicle bodies are air-driven hydraulic rams and have basically the same structure as those used to repair panels.

On its own a hydraulic ram can virtually only produce force in a pushing direction. However, by combining a ram with chains it is possible to produce force in a pulling direction.

■ Hydraulic units and work



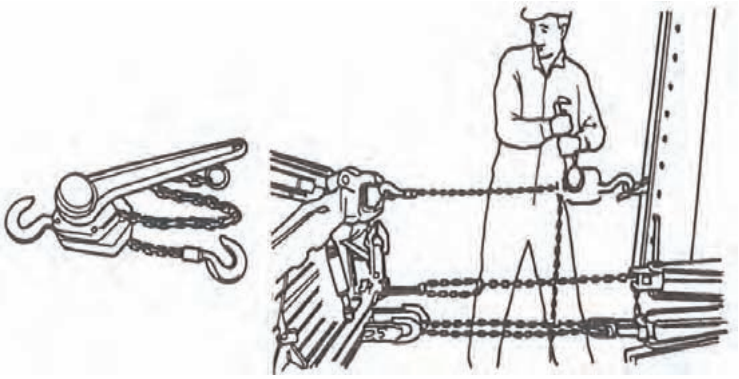
■ How to convert stretching force to pulling force



In reality, the pulling direction will not change as shown in the diagram

3) Chain puller

Not only hydraulic rams produce large pulling force. Wire pullers and chain pullers are used as tools that amplify human force in a pulling direction. Both produce force by reeling wire or chain. Although it is a person who reels the wire or chain, a continuous large force can be used because the reel has a lever that multiples the force.



4) Pulling systems

Damage that hasn't affected the underframe can be repaired using pulling systems that use chains, clamps, hydraulic rams, chain pullers, floor anchors and rails.

The extent to which a vehicle is firmly anchored varies according to the size of the force that is to be applied.

(3) Three elements of force

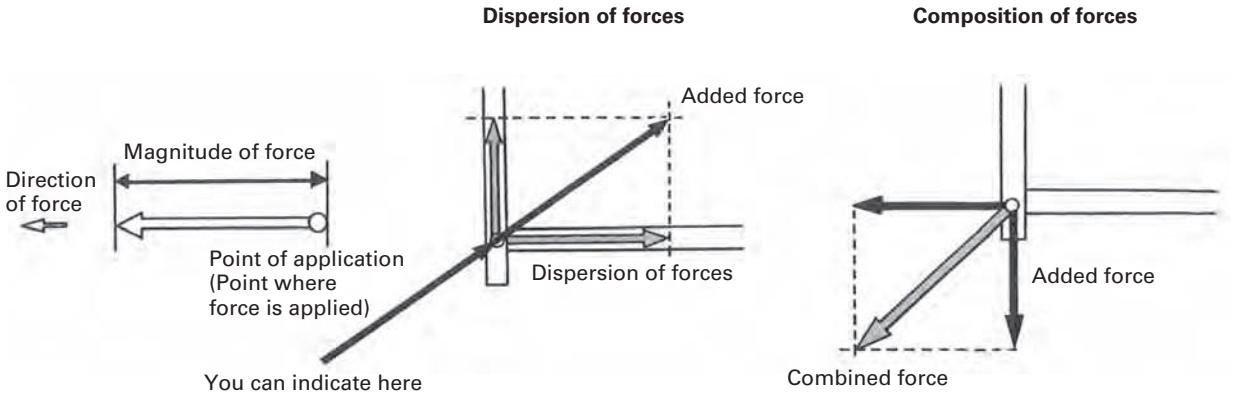
1) Magnitude and direction

Magnitude, direction and point of application are the three elements of force.

Arrows are often used to express the magnitude and direction of force. Magnitude is shown by the length of the arrow and direction by the direction of the arrow. This type of representation is known as a vector.

When represented by a vector, it is easy to imagine the composition and dispersion of force. Composition can be thought of as a single force made from two or more forces applied from other directions. Dispersion is the way in which force applied from a certain direction spreads and transmits.

■ Methods of expressing force

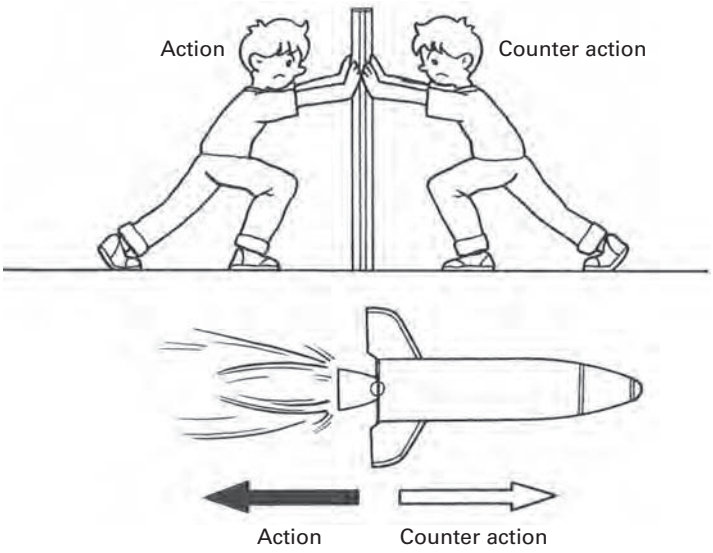


2) Principle of action and counteraction

When force is applied to an object, the same amount of force is produced in the opposite direction. For example, if a drum on the ground is pushed with a force of 10N it will produce a counter force of 10N in the drum in the opposite direction. This force functions as a kicking force against the ground by the person who is pushing the drum. Therefore, when the ground where you kick is slippery like ice and thus the counter force is not able to be transmitted to the ground, the drum won't move at all no matter how hard it is pushed. The initial pushing force is called action and the repellent force is called counteraction.

Rockets and jet planes fly in the sky because of the force of the counteraction in the opposite direction to the force injected by burning fuel.

■ Action and counter action



When pulling force is applied in a pulling direction to a body that is anchored to an alignment system, the body will produce a reaction force in a pushing direction toward the alignment system and the alignment system will produce a similar reaction force in a pushing direction toward the floor or bench. Accordingly, force more than that which can be sustained by the anchoring system cannot be applied to the body. Also, since force is also applied to the body where it is attached to the anchoring system, if that section is weak it will not be possible to apply a large amount of force.

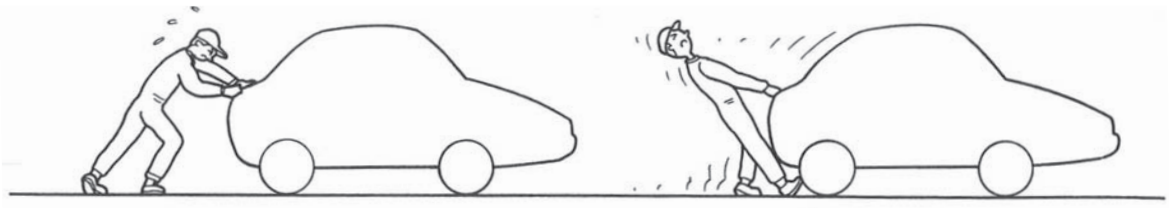
3) The action of inertia

When the same amount of force is applied, it acts differently depending on whether the force is applied slowly or whether the same force is applied momentarily. For instance, if a certain amount of force is steadily applied to a stationery vehicle, the vehicle will start moving in the direction to which the force has been applied. However, if a huge force is applied momentarily, the area to which the force was applied will deform. This is how inertia works.

In other words, inertia means that a body in motion tends to remain in motion and a body a rest tends to stay at rest. Inertia is in proportion to the weight of the body.

Force received by a car in an accident is momentary force. Therefore, even though a vehicle that is not anchored, it will not produce moving force and as a result the body will deform. In contrast, force applied when repairing is applied slowly. Consequently, if the body is not firmly anchored the vehicle will move. The force will also have a wider effect than the force did in the accident.

■ Inertia

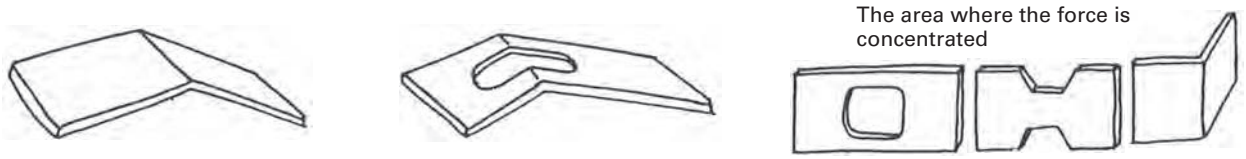


Heavier objects are more difficult to move, and once they move, you need larger force to stop them

4) Concentration and dispersion of force

When force is applied at one site to a material made entirely of the same substance and which has a uniform shape, the force will be transmitted throughout the entire material. If the force exceeds the strength of the material, it will deform or break, but where that will happen can't be known until it occurs. However, if the area or shape of a material varies, for example it suddenly narrows or there is a site where it folds over, it will always deform or break at those points. This is because the force is concentrated in these areas. This is called the concentration of stress.

■ Concentration of force



When the whole area is even, it depends on the way of applying force for where to be bent

If there is an area where the force is concentrated, it is always bent from this section

Punched hole

Change in sectional area

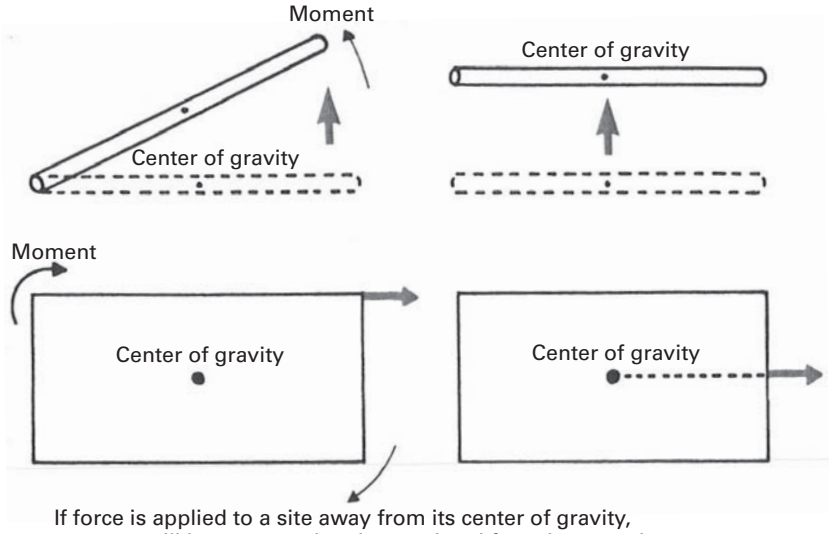
Curve (corner)

5) Moment of force

Objects have a center of gravity, which we can think of as the place where that object's weight concentrates. This isn't always the place that appears to be its center.

Force applied to the center of gravity can be seen as applying force to the entire object. If the object is not anchored, it will move in the same direction as the applied force. However, if force is applied to a site away from its center of gravity, the force will act as a rotational force centering on the center of gravity. This is moment.

The anchored parts of an anchored object will behave like that object's center of gravity. When force is applied to an anchored body, force will be applied to unexpected directions if thought is not given to the anchored points and the direction of the force.



If force is applied to a site away from its center of gravity, moment will be generated and a rotational force is created

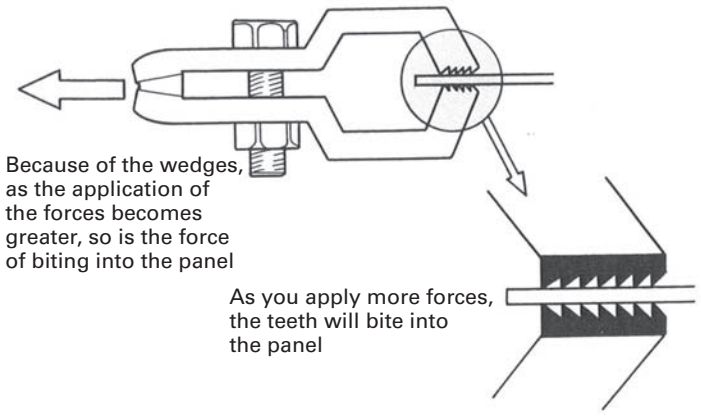
(4) Clamps

1) Structure of clamps

Clamps are used so that force can be applied when pulling the body. Although clamps are generally tools used to hold something or to clasp something, clamps are used in alignment work as tools that are attached to panels and to which force is applied.

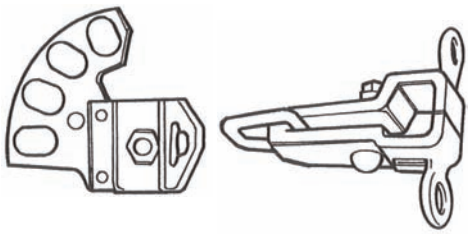
With the exception of special clamps, clamps used for pulling have two rows of teeth that clip onto a panel or flange. The teeth are pressed against the panel by tightening a bolt. If the pulling force is correct, the more that force is applied the more the teeth will take on a shape that sinks into the body. The bigger the area of the teeth the greater the amount of force that can be applied.

Although the part that clamps the body is similar for every shape of clamp, the clamp itself comes in various different shapes. This is so that they can be attached anywhere on the body. There are clamps that can be used universally in various different places and those that are for use in a special single site. Clamps can be divided into the following broad categories.


Because of the wedges, as the application of the forces becomes greater, so is the force of biting into the panel
As you apply more forces, the teeth will bite into the panel

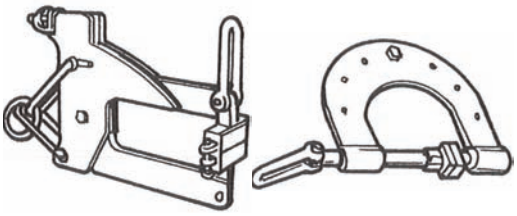
① Universal clamps

These are attached to flanges or the end of panels. They come in various shapes and sizes and can be used for a wide range of sites.



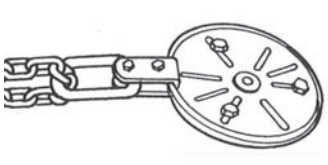
② Vice clamps

Because vice clamps have a large throat they can be attached to the body over an obstacle. Vice clamps are used in areas where universal clamps cannot be used, such as an edge with a box structure, like the roof and floor, and for clamping a pouch panel that uses service holes. They are also known as C clamps because of their shape.

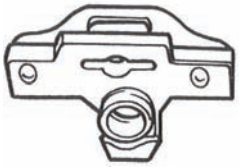


③ Special clamps

These are clamps with shapes made to fit the body and panels. They can be used only on specific sites. They include blade clamps used for bolt holes in struts and narrow clamps used on the roof rail.



For strut tower



For fastening the body (floor type: a set of four)

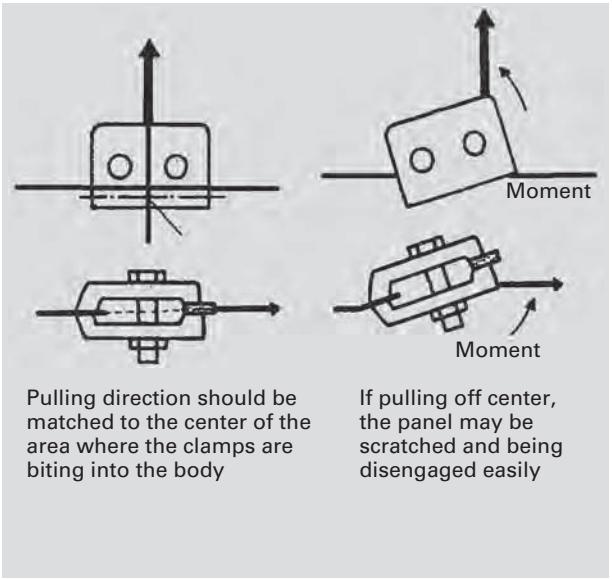
2) Clamps and pulling direction

Clamps are designed to be pulled front to back, up and down, and right to left. The pulling direction is determined by the structure of the clamp. A clamp cannot be pulled in any direction.

The extended line of the pulling direction must pass through the center of the teeth. If this is not exact, moment could cause the teeth to slip and the clamp to break.

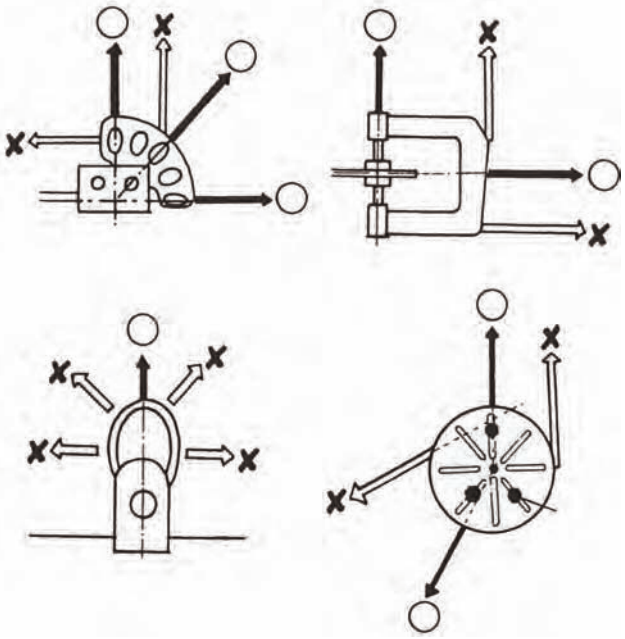
This precaution applies to every type of clamp.

■ Correct way of pulling clamps.



Pulling direction should be matched to the center of the area where the clamps are biting into the body

If pulling off center, the panel may be scratched and being disengaged easily



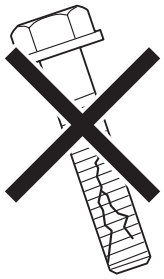
3) How to handle clamps and chains

If clamps are handled badly they can't be used for long, work efficiency falls and the risk of accident increases. Be mindful of the following points in the daily use and maintenance of clamps.

① Check the clamp's teeth

A large amount of force is applied to the body via the teeth on a clamp. If the teeth are in bad condition, the force will not be transmitted. Teeth have a triangular profile so that when force is applied they will grip the panel and not slip. If the teeth become round or dirt gets in the gap between the teeth, their ability to grip will decrease and it will be easier for them to come off. Clean and check the teeth regularly.

② Don't over tighten the bolt



Sometimes the bolts around the teeth that prevent the clamp from slipping or coming off are tightened more than necessary. However, because pulling force acts in the direction that the bolts are tightened, they can't come off even if a large amount of force is applied. A bolt will get damaged if it is tightened with more than the appropriate torque. Check clamp bolts regularly, remove dirt and dust from the grooves and coat them lightly with machine oil. Replace cracked or deformed bolts and nuts with new ones.

③ Don't twist chains

Chains which transmit force to the clamps play an important role in body repair. Chains of a size specified for the alignment system have some margin as far as strength is concerned. They do not break as long as they are used normally. However, it is dangerous to use a smaller chain than the size specified or to use and old chain that has rust.

Using even a specified chain when it is twisted will apply undue force, and even if it doesn't break suddenly its strength will be decreased. Always make sure a chain is not twisted and protect it by occasionally applying some machine oil.

(5) Pointers

1) How to determine the pulling direction

In the case of comparatively light front damage, repairs can be made by following a certain method regardless of the condition of the damage. Let's take the example of a vehicle that received an impact from the front on the left side on a diagonal. The left side of the front body is pushed toward the rear while the whole vehicle is bent toward the upper right. The damage stopped at the side member and the toeboard has not been affected.

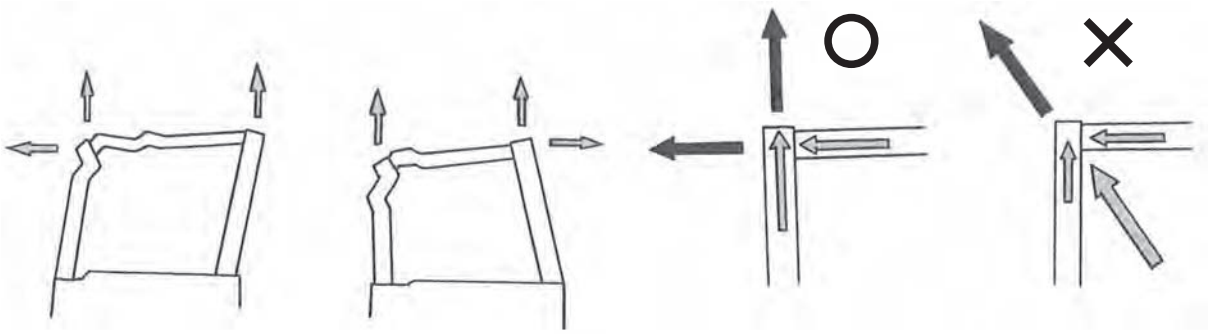
Since the impact was from the front left on a diagonal, one would think that the pulling direction is also the front left on a diagonal and that since the vehicle is bent slightly up to the right force should be applied in a slightly downwards direction. However, this would be wrong.

Even if the front is pulled on a diagonal from the front, the force will disperse to the direction of the side member and the radiator support, which would not be effective. The clamps would most likely come off. If the pulling direction and the panel surface to which the clamps have been attached are not aligned, bending moment will act on the clamps and the clamps will come off and the panel to which they were attached will be deformed.

It is best if the panel surface, surface to which the clamps are attached and the pulling direction are all aligned. In other words, you should pull from virtually face-on despite the deformation of the side member that has been pushed back. This will make the most effective use of the pulling force. In the same way, you should pull on the deformed radiator support and cross member from virtually side-on while being drawn into the side member. For the right side member that is bent slightly upwards, force should be applied from straight in front of the front. The basic rule is to apply force from these three directions.

To put it more precisely, envisage the damage panel returned to its correct position. Decide on an angle which will allow a straight pulling direction. This point requires considerable thought. Generally speaking, vehicle body panels are a combination of vertical and horizontal panels, and because there are no panels in a diagonal direction always decide to pull from straight in front or from the side square on.

■The concept of pulling direction



Regardless of the directions of deformation, the pulling direction should be straight against the body structure

Force is applied effectively. Can be repaired even with small forces

Since forces are dispersed, stronger force is required and there is a possibility of clamp slips and generation of deformations on the normal area

2) Spring back

When force applied by pulling is released, the panel which should have been fixed compresses and moves back considerably. This is because of elasticity in the sheetmetal and the deformed area has not been able to stretch due to work hardening of the deformed area.

Compression of a panel for a second time after force has been released when pulling is known as springback. Repair work is more efficient if springback is minimized. The following three points are important for avoiding springback.

① Extra pulling

Even if while pulling the panel has resumed its original measurements, if you pull an extra once or twice even if there is springback you will get closer to the original dimensions.

② Hammering while pulling

Because a deformed area that has work hardened (plastic deformation) is stronger, the deformation won't come out even if you apply force by pulling and a panel in another place will be stretched.

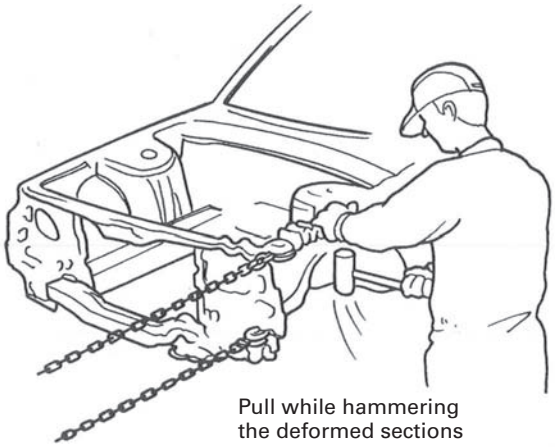
Hammer the deformed site while applying some force, and if the residual force from the accident in the deformed site is released while it is being aligned springback will decrease.

③ Don't pull once

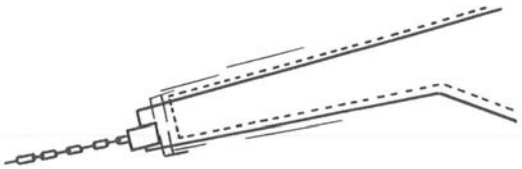
Pulling force not only corrects the deformed area but also pulls normal areas. Consequently, as long as the damage is not too minor, instead of applying a huge amount of force all at once, correct the deformation by pulling a little and hammering, slacken the force to check the springback and then apply the force again.

If strong force is applied all of a sudden, the lower elasticity in the deformed area could cause cracking.

■ Pulling pointers



Pull while hammering
the deformed sections



Pull a little further by taking
springback (moving back)
into account

Chapter 10 Handling of welding equipment

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1. Welding methods and types

Spot welders and MIG welders are mainly used for replacing welded parts.

Welding using a spot welder, the same method used in the manufacture of new vehicles, is by far the more common method. However, because the performance of welders used for repair work is not as good as those used during production, reliable repair, such as increasing the number of welds, is required.

A MIG welder is used for ① sites that require strength; ② sites where spot welding can't be used; and ③ sites that require patches and spot welds.

Joins made using an oxyacetylene welder, which used to be universally used, have insufficient strength so are not used any more.

MIG welders are mainly used for aluminum alloy panels instead of spot welders. As for plastic, since most materials are thermoplastic, use a welder made for welding plastic that generates heated air. The welding rod should be made from the same material as the material being welded.

Rustproofing is essential when welding metal panels. Make sure you apply an antirust agent used for welding before you start welding.

2. Spot welding

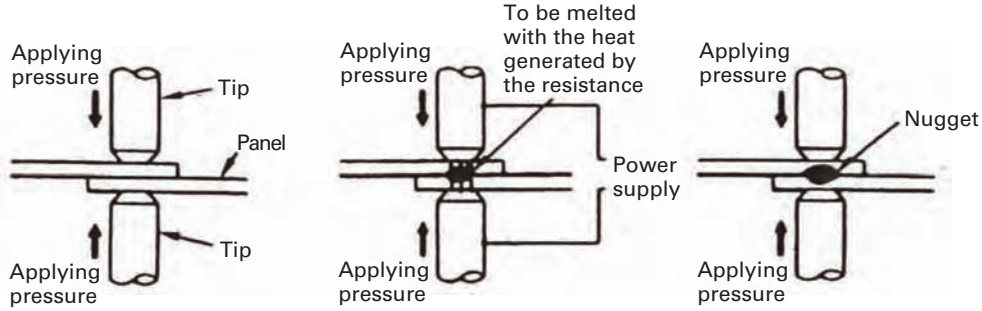
(1) Principles and characteristics

Spot welding also goes by the name electrical-resistance welding. As the name suggests, the joint section of the panel is melted and joined using heat generated by the resistance of the welding current through the panels.

Clamp the two panels using copper electrodes (tips). Once the panels are attached under pressure a strong current melts the welding surface of the panels. When the current is stopped, pressure is maintained until the weld cools, which strengthens the weld (nugget).

One main feature of spot welding is that technically it is relatively simple and can be done quickly without much experience. Because heat is applied to one site only, the heat has minimal effect on the surrounding area, thus restricting distortion.

■ Principles of spot welding



Applying pressure

Apply pressure on to the part to be welded of the lapped panels and they are adhered so that the current flows easily.

Electroconductivity

With pressure being applied, apply a large current so that the contact surface of the panels is melted and welded together.

Holding

Even after applying current, continue applying pressure until the welded part cools down so that the welded part (nugget) will be reinforced.

(2) Components

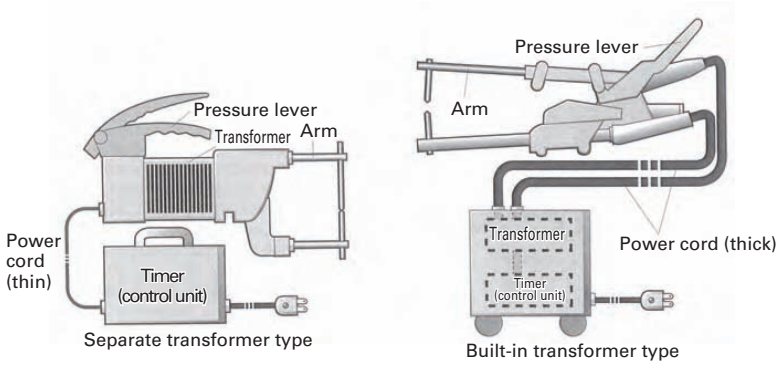
A spot welder consists of a welding gun (arm) with electrodes, a transformer and a timer. Some welders are integrated units where the transformer is built directly into the welding gun, while some use a separate transformer.

Because in integrated welders the arms are heavier, a certain degree of strength is required to hold the gun at the weld site. The weight is relieved by using an overhead boom.

Continuous welding causes the gun to heat. This is the reason some welders are water-cooled or air-cooled.

There are multi-functional spot welders that can also be used to weld washer studs used in body repair. Recently, high quality welding has become possible using a system in which a computer controls the welding conditions appropriate for the purpose, panel thickness and the material being welded.

■ Spot welder components



(3) Gun

The arms on a welding gun must be able to press the electrodes against the workpiece no matter the location of the site. Accordingly, a spot welder comes with a range of arms in different sizes and shapes. Use an appropriate arm for the site.

Most arms are pressurized and held using air

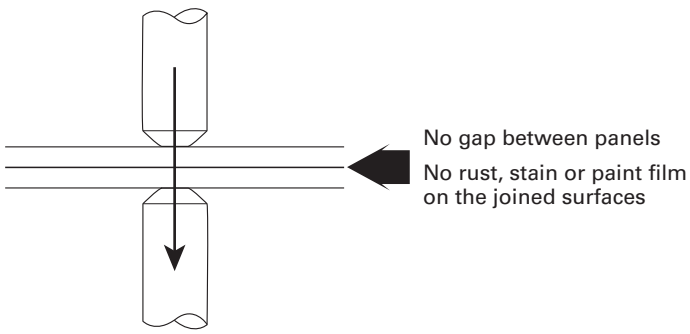
Choose the shortest possible arm for the welding site.

1) Electrode tips

① In-line

Electricity won't flow if the upper and lower electrode tips pressed against the workpiece aren't in a straight line. This also means that the arms are parallel. Strength is significantly reduced if the arms are on a slight angle.

■ Electrode tips must be in line

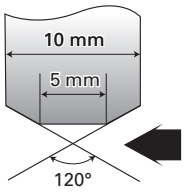


② Tip shape

If the tip of the electrode tips do not make contact parallel to the workpiece they cannot function properly. The prescribed shape should be maintained as this has an affect on quality.

The diameter of the ends of the tips depends on the thickness of the workpiece. If the panel is thick, the area of the tip will be larger as it has to generate more current. The following formula is used.

■ Shape of tip



It should not be angled due to wears or there should be no dirt or scratches

· Electrode tip diameter

2t + 3 mm = diameter t is panel thickness

* If sheets are of unequal thickness, calculate using the thickness of the thinner sheet. For example, if there are sheets measuring 0.8 mm and 0.9 mm,

the formula is: panel thickness 0.8 mm × 2 + 3 = 4.6 mm

Use a tip cutter or file when: ① the tip diameter is too big; ② the upper and lower tips do not engage properly; and ③ there is dirt on the surface.

If a tip is worn or bent replace with a new tip.

① Pressure (welding force)

Since quality will be affected if a certain amount of pressure is not exerted during spot welding, before welding check the pressure using a test piece with the same thickness as the welding site. Old panels due to be discarded are useful for this purpose.

(4) Welding criteria

Criteria to be considered when spot welding are the weld current, time, pressing force and tip diameter. These vary depending on the thickness of the panel.

These criteria can also vary due to the characteristics of the spot welder being used. Optimum results can be obtained by inputting data such as panel thickness so that the welder automatically controls these values.

(5) Conditions of use

1) Surface conditions of the joined panels

There should be no gaps, paint or rust in the surfaces to be joined. The tips must be pressed tightly against the panel surfaces.

2) Rustproofing treatment on the surface

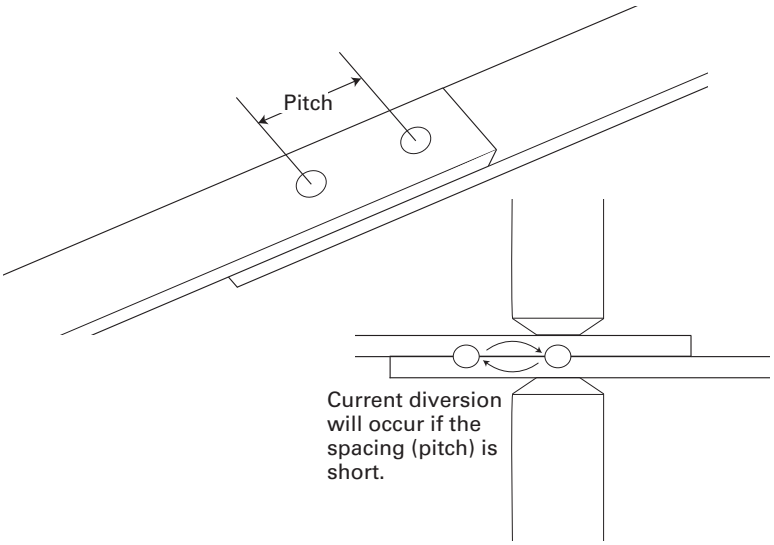
Treat the surfaces to be joined by applying a rustproofing sealer beforehand. Rustproof sealers used for welding conduct current.

3) Weld pitch

When spot welding continuously, current diversion will occur if the spacing (pitch) between the present site and next site is short. Some of the current will be lost because it will try to reach the previous weld site where resistance is low. Since there is not the expected level of current flowing, the strength of the latter site will be lowered.

It is for this reason that you should weld while maintaining certain spacing. Spacing between weld sites should be more than three times the diameter of the weld nugget.

■ Weld pitch



4) Number of weld points

Refer to the body manual for the locations of the spot weld points. Make a weld point in the center of the flange.

In vehicle repair it is often not possible to retain the spot points of a new vehicle. Taking the performance of a spot welder used for repair into account, around 1.3 times as many weld points as that on a new vehicle will ensure that strength is maintained. In MIG plug welding the same number of weld points as a new vehicle is acceptable.

5) Panel thickness limit

Although it can vary depending on the performance of the spot welder being used, generally spot welding should be done on panels no thicker than around 3 mm. MIG plug welding should be used for greater thicknesses.

6) Heating of tips

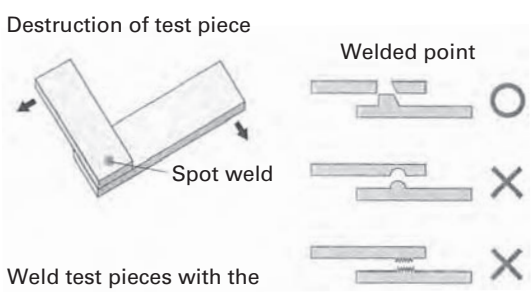
The electrode tips will become heated if welding continuously. Because when tips heat up ① the current is impeded; there is ② friction; and ③ "dishing" occurs, either take a break after a certain number of times or use a welder with a cooling attachment.

(6) Inspecting the finish

There is a limit to the results of spot welding that can be ascertained in a visual check. Although a visual check will show spacing and dishing, it won't show any cracks.

For this reason, it is important to weld a test piece beforehand under the same conditions, remove it and check its strength.

■ Spot weld tests



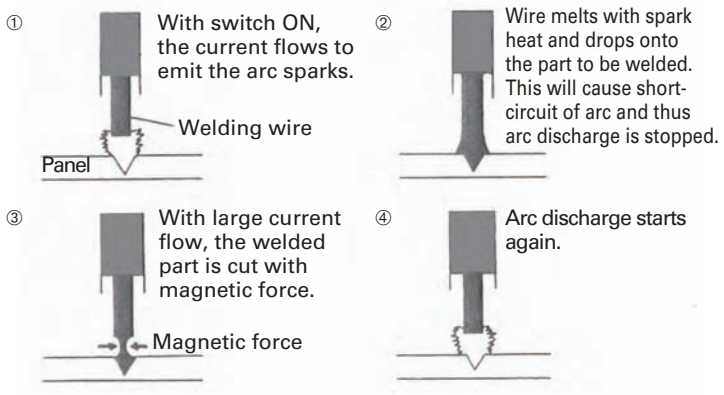
Weld test pieces with the same thickness as the panel to be welded.
Then separate the test pieces.
Chisel and hammer can be used to remove the welded point.

3. MIG welding

(1) Principles and characteristics

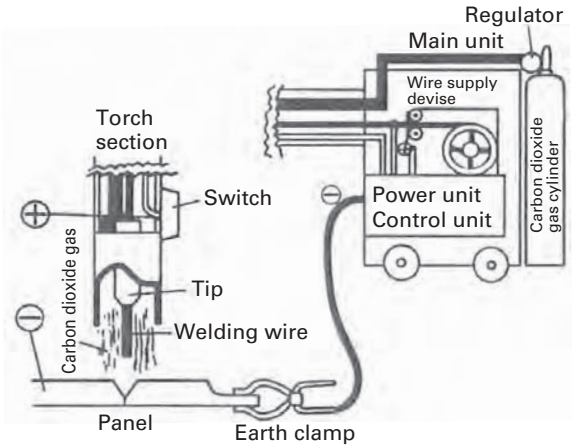
In MIG welding, the welding wire is the electrode and is melted by the heat of the arc within an inert gas shield. It is also known as semi-automated welding as when the switch is turned on the wire is automatically fed through.
TIG welding also uses the heat generated by the arc. The electrodes are tungsten so they do not wear. The arc produced by the electrodes melt the welding rod. This requires the use of both hands.
The small torch used on one side only means that MIG welding can be used in a variety of sites. Another feature of MIG welding is that it can be used to weld panels of unequal thickness.
A MIG welder is used for sites that are inaccessible for spot welding, sites that require strength, and for patches on panels.
Distortion is minimal and basic operation is relatively simple. A direct current power source of 200 V is used.
Plug welds (spot welds) and seam welds (butt welds) are mostly used when repairing panels. Plug welds are made at sites that are inaccessible for spot welding. A plug weld is made by removing the paint film, making a hole in the upper panel and then filling up the hole. A seam weld is where a 1 – 2 mm gap between panels is filled in.
If there is a site where it is difficult use these methods, make a fillet weld on the end of two overlapping panels.

■ Principles of MIG welding


①
With switch ON, the current flows to emit the arc sparks.
Welding wire
Panel
②
Wire melts with spark heat and drops onto the part to be welded. This will cause short-circuit of arc and thus arc discharge is stopped.
③
With large current flow, the welded part is cut with magnetic force.
Magnetic force
④
Arc discharge starts again.

(2) Components

A MIG welder consists of the weld torch, which feeds the wire and shield gas, an earth clamp, a mechanical unit with a built-in wire drum (some welders have an external wire drum), and a gas cylinder positioned to the side.



(3) Main unit

Voltage, current, and the timer are controlled within the main unit. By calibrating the control panel, the welder will set the appropriate values.

(4) Wire feed unit

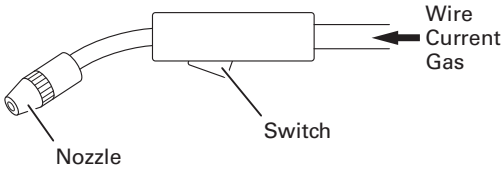
This unit consists of a wire reel and a wire feeder. The wire reel is housed either in the main unit or in a separate unit.

The wire comes in a variety of diameters and materials. Wire diameters include 0.6 mm and 0.8 mm, and if the workpiece is an aluminum alloy panel, aluminum wire should be used.

Check the wire feed unit daily and remove dust and oil.

(5) Torch

When the switch is pressed, it feeds the wire through which the electric current passes as well as gas through the nozzle. Since it is used as a conduit for electricity and gas and is exposed to high temperatures, the torch is the most susceptible to wear of all MIG welding components.



(6) Gas cylinder

The abbreviation MIG stands for Metal Inert Gas, which is used to form a shield around the weld site. This prevents rust, minimal gas is used and it produces a tidy finish.

However, argon, an inert gas, is expensive and though it is used for aluminum alloys, an activated gas (metal active gas) or a gas made up of a mixture of carbon dioxide and argon is used for normal sheetmetal. Since the majority of welders use carbon dioxide gas it is more correct to call this welding MAG (metal active gas) welding. However, the term MIG welding is commonly used for this method.

This commonly used carbon dioxide gas has a specific gravity of 1.529 and with a melting point of -56.6 ˚C. It is a gas at room temperature. Carbon dioxide gas is colorless, transparent, tasteless and odorless.

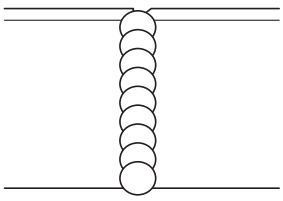
The gas cylinder should always be upright. Use a belt or chain to stabilize it and prevent it from tipping over. When exchanging the cylinder make sure it does not receive an impact.

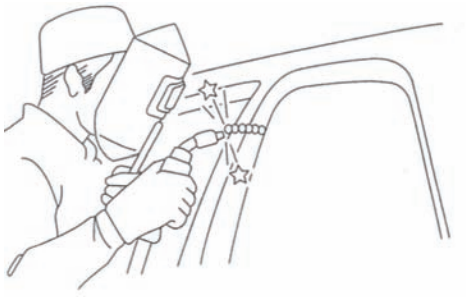
Gas cylinders are color coded to allow immediate identification of the contents. Carbon dioxide cylinders are green and argon gas cylinders are grey.

Cylinders are fitted with a gas regulator. Lower the cylinder pressure (2 – 3 kg/cm^2) and adjust the gas flow rate so that it is appropriate for welding. As evaporation heat causes carbon dioxide gas to freeze when it leaves the cylinder, so a heater is attached to avoid this. Check for gas leaks from the regulator daily using a soap and water solution.

(7) Welding

1) Seam welds

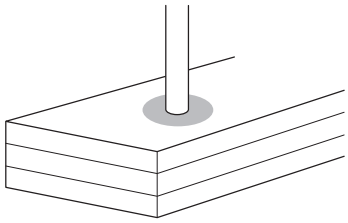


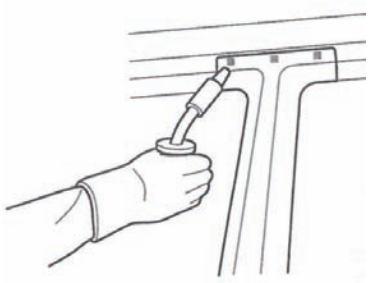


Seam welding is when two overlapping panels are welded. Secure the two panels leaving a gap of 1 – 2 mm between them, and weld continuously while filling up the gap.

Because heat will cause distortion in the surrounding area if you attempt to weld a long distance at once, make a weld, stop for a moment and then continue with suitably spaced intervals.

2) Plug welds (spot welds)

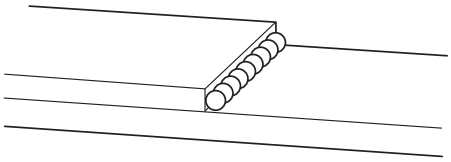




Plug welds are made to supplement welding done using a spot welder. Plug welds are made at sites where there are a number of panels to be joined, sites that require strength, and sites where spot welding is difficult.

First, make a hole in the top panel at the weld site. The diameter of the hole varies depending on the thickness of the panel. A diameter of 5 – 6 mm is suitable for a 0.8 mm-thick steel sheet.

3) Fillet weld



A fillet weld is used to weld the ends of one panel laid on top of the other.

(8) Conditions of use

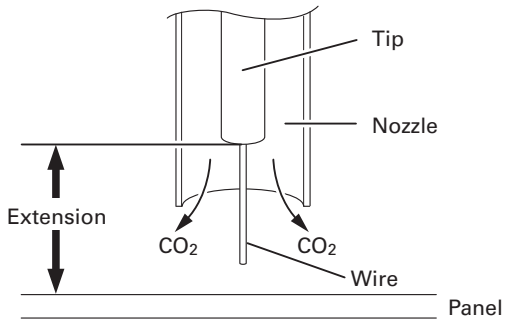
1) Weld area

Do not leave a gap between panels and perform the necessary rustproofing treatment. Remove any rust or moisture.

2) Distance

If the distance between the end of the tip in the nozzle and the workpiece is too far the distance from the wire tip will also be far. This will reduce the current, which will result in shallow penetration. Conversely, if the distance is too short, the large amount of current will result in deep penetration. Accordingly, if you make allowance for this you will be able to weld panels of different thicknesses without having to adjust the current.

■ Distance from torch



3) Alignment

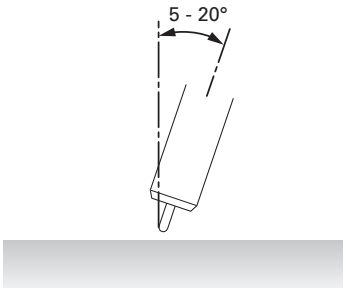
① Plug weld

Position the tip of the wire in the nozzle so that it is perpendicular to the center of the hole being welded. If it is not in the center there will be insufficient penetration to the lower panel.

② Seam weld

Put the wire tip in the middle of the bead. The torch should be at a 5 – 20˚ angle to the direction of the weld.

■ Torch angle



③ Fillet weld

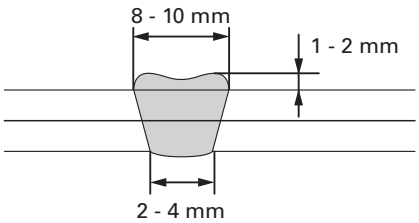
First, spot weld in a way of plug welds leaving a certain distance apart and then weld in a way of seam welds to fill up the gap.

(9) Quality check

To check whether or not the weld is correct, use a panel offcut making it the same thickness, etc and check using a lapped splice. Check the size of the weld diameters on both sides and then conduct a twist test.

The diameter of a plug weld should be 8 – 10 mm (2 – 4 mm on the rear panel), and should be raised 1 – 2 mm.

■ Plug weld diameter



(10) Safety precautions

1) Welding arc and sputters

Arc welding produces a strong arc that contains ultraviolet rays. Place the workpiece so that you don't have to look directly into the arc. Wear welding gloves and do not expose skin directly, including the arms. Exposed skin can be burnt by not only the arc but also by weld sputters. Make sure work clothing is buttoned or zipped.

2) Fire

Since welding generates sparks, make sure there are no hazardous items like gasoline or thinner in the work area.

3) Gas cylinder

The gas inside the cylinder is liquefied and compressed. Use a cylinder that is not damaged, do not subject it to any impact and avoid sudden temperature rises, such as exposing it to direct sunlight.
Handle carefully when replacing or shifting.

4. Oxyacetylene welder

Oxyacetylene welders were once commonly used. However, this type of welding is no longer used in body repair due to distortion caused by heat, the occurrence of rust after welding, and insufficient strength. Shrinking is also mainly carried out using electrodes. Today, this is limited to heating or cutting panels no longer in use.

■ Gas welder components

① Oxygen cylinder

The cylinder contains oxygen compressed to approximately 150 kg/cm^2. The cylinder is black.

② Acetylene cylinder

Acetylene is dangerous. It is stored in a cylinder that contains a porous material and is dissolved in other chemicals. Pressure is 15.5 kg/cm^2. An acetylene cylinder is brown.

③ Oxygen valve

④ Acetylene valve

⑤ Oxygen regulator

Lowers and maintains the pressure of the oxygen as it leaves the cylinder.

⑥ Acetylene regulator

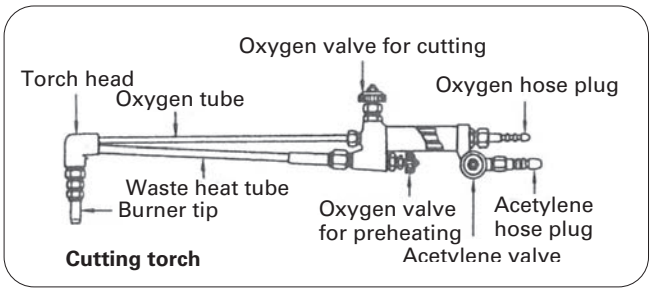
Lowers and maintains the pressure of the oxygen as it leaves the cylinder.

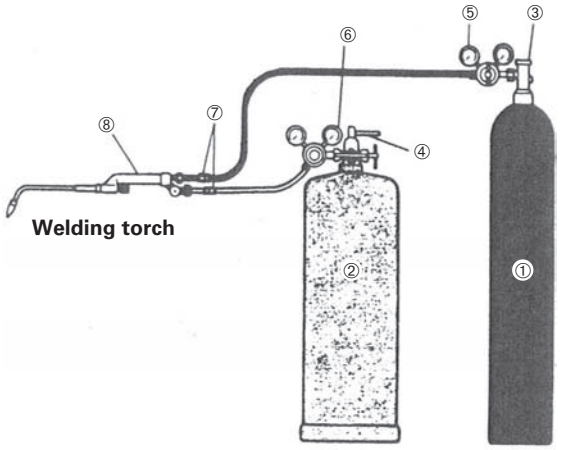
⑦ One-touch hose connection

The hose used for oxygen is also black and the acetylene hose is also brown.

⑧ Torch

The amounts of oxygen and acetylene can be adjusted separately. There are torches used for cutting and torches used for welding.





Chapter 11 Replacement of welded panels

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1. Replacing welded panels

Welded panels can be replaced by either using a supplied assembly or by removing one section and replacing that section with a patch.

(1) Assembly replacement

This method involves replacement using a supplied panel and is used for parts such as the radiator panel, front wheel apron, rear skirt and roof panel.

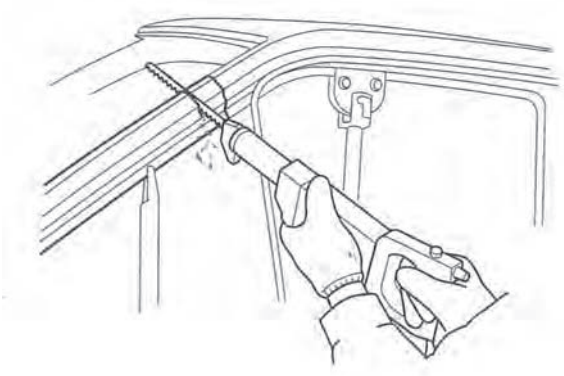
(2) Patch replacement

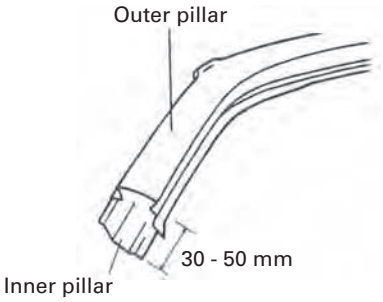
This is when the damaged area is cut out and replaced with a patch.

In general, if a reinforcement has a complex construction, rather than replacing the whole reinforcement a section is cut out and replaced with a patch. This is a more efficient method. Accordingly the rear quarters, side sills, and center pillars can be easily replaced using this method. In addition to showing structure and strength, a body manual also shows the best sites for cutting and the number of weld points.

The basic rule of thumb is to cut out leaving a 50 – 100 mm margin to a panel corner or welded section. Patches are best used on sites where there are no reinforcements on the under side and the length of patch welding is kept to a minimum.

When replacing both the inner and outer panel of a pouch-shaped part like a pillar, stagger the cuts of the inner and outer panel by 30 – 50 mm. Leave inner panels on the body side long and shorten upper outer panels.

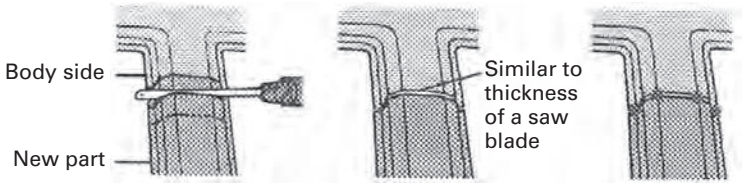




1) Joining

Butt welds are often used when replacing parts that have been cut out. MIG weld the gap between the new cut panel and the old panel on the body. After welding the key spots, fill in the gaps and weld the whole part.

A seam of the thickness of an air saw blade is appropriate. You can either put the new and old part together and cut once or cut using accurate measurements. When cutting using measurements, if the cut piece is too short there will be a gap between the panels. To avoid this, leave an extra margin when cutting and make adjustments at the end.



Put the new and old panels together and cut once

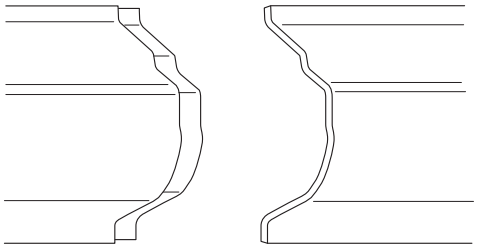
Positioning with a space similar to thickness of a saw blade

Spot weld with appropriate interval to fill in the gaps.

2) Flanging

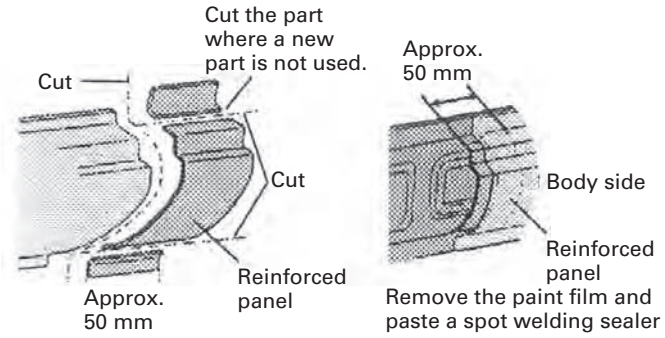
Create a flange on one of the panels using a flanging tool and attach by either MIG welding a fillet weld or by using a structural adhesive.

This is restricted to sites where flanges can be made. Ordinary flanging tools are used on flat surfaces. However, there are some tools used in panel bonding that can be used on crowns and corners.



3) Adding reinforced panels

Use leftover parts of new panels that have been cut for sites that require reinforcing. Cut the same press line to a length of around 50 mm and weld the part under the body side as a reinforcement panel. Strength is further improved by laying the new panel on top and making a butt weld. This method is suitable for the side sill and side frame.



Remove the paint film and paste a spot welding sealer

2. Order for replacing welded panels

(1) Removal of damaged sections

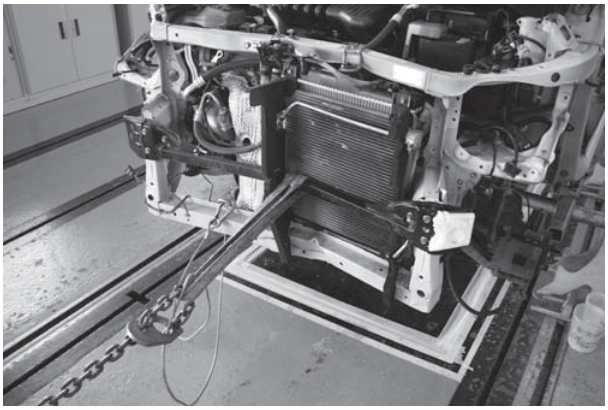
1) When to remove parts

Unlike a bolted on panel, once a welded panel is fitted its position cannot be adjusted. Therefore, this work needs to be done carefully.

The welding of new panels should be done in association with body alignment. If the measurements of underframe parts can be corrected during alignment, remove panels that will be replaced with new panels.

However, if this is done too soon, the dispersion of force to surrounding parts during the remaining repair work will not go well and could take longer. Conversely, if you wait until all body repairs have been completed, it will take longer.

The basic rule of thumb is to remove parts once the measurements of key points for welded parts have been corrected or when they align perfectly with the measurements of the adjoining panels.



Do not remove the panel being replaced until the dimensions have been corrected.

2) Rough cuts

Decide on the sites to be cut out and make a rough cut.

Since panels that are to be removed don't have to be repaired, if necessary to make repair work more efficient cut out these sites before the panels are removed.

When make a rough cut, be careful not to cut wire harnesses and tubing on the underside or in pouch structures. Reinforcing materials filled inside pillars must not be burned.

When working on a particular vehicle model for the first time make sure you refer to the service manual beforehand.

When making a rough cut for a patch, leave a margin of an extra 30 mm on the body side.

Use an air saw or plasma cutter for cutting. If using a tool that produces a lot of noise, insert ear plugs or wear ear muffs.

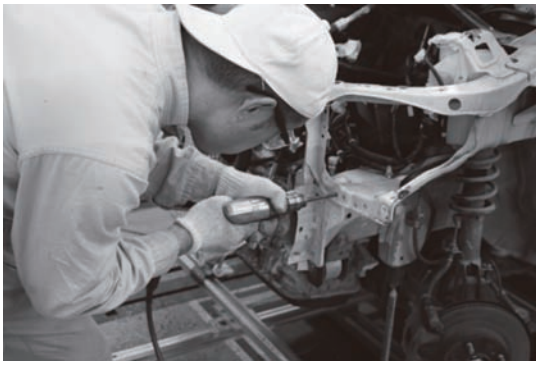
3) Drilling out spot welds

Using a drill or a dedicated spot drill, remove nuggets on spot welds by grinding.

Make sure you grind only the upper panel and not the lower panel. A spot drill can be adjusted to the thickness of the panel.

Do not use an ordinary blade with a pointed tip. Use an almost flat dedicated blade (spot cutter).

When there are three layers and the panel being replaced is under the remaining panel, go all the way through. Use a MIG welder, weld a plug into the hole in the remaining panel.



4) Taking off the panel

Insert a chisel into the gap in the panel on which you used the spot drill, tap it with a hammer and take off. Apply force in the direction in which you are taking off the panel so that the panel on the remaining side is not marked.

Also use a chisel and hammer to take off chips from the old panel that remain on the edge.

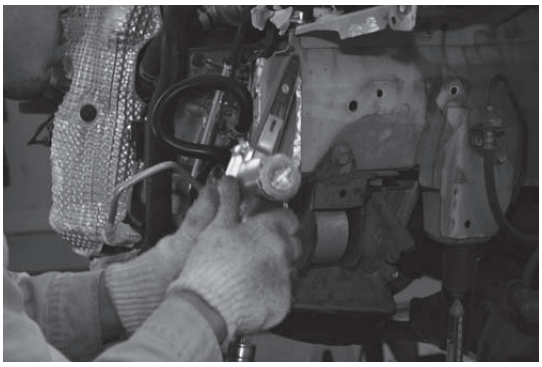
Lastly, with a hammer and dolly repair any dents or bumps formed in the welded part.

(2) Preparation for fitting

1) Treating panels

After removing the panel, use a belt sander to smooth any spot-weld traces on the panel to be used.

Repair damage to spot welds or pierced sites that occurred during removal using MIG welding.



Smooth using a belt sander

2) MIG plug weld holes

Make a hole about 6 mm in diameter in the upper panel at sites that are to be welded with MIG plugs. Use an air drill or punching tool.

Using a belt sander, remove paint film on the body side and new part side taking off more paint than the size of the hole.

Use a drill to make holes

3) Preparation for the new panel

When cutting out to make a patch, cut it out with an air saw or plasma cutter leaving a margin of around 30 – 50 mm on the body side.

(3) Fitting

1) Trial fitting and final cut

Trial fit the new panel by clamping it in place.

If the panel needs cutting, place the two panels one on top of the other and cut simultaneously using an air saw. If this is not possible, cut in line with the final measurements. Do this gradually, not in a single step.

In the trial fit, check the measurements and fit any related panels, adjacent panels and bolt-on panels and looking at the whole arrangement determine whether they are aligned.

Using a tram gauge, compare with the reference values in the body dimension diagram.

If the position is fine, take it off and prepare for welding.

2) Paint removal and rustproofing

Remove any primer coated on the new panel and paint on the weld sites on the body side, on both the front and back. Use a belt sander.

Apply a welding rustproofing sealer to the area where the welded panel will be placed.

If there are sites requiring a coating of sealer that will be hard to get to once the welding has been done, apply the sealer beforehand.

Before fitting, compare it with the old part to see whether it has enough small panels, such as reinforcements. If there aren't enough and if the reinforcements in the old panel are not marked or damaged, take them out and weld them to the new panel first.

Rustproofing weld sites

3) Number of weld points

Although in spot welding the number of weld points also depends on the power of the welder and repair site, increase the number of weld points by about 30% so that outer panels have 10% more weld points than a new vehicle and underframe panels have 30% to 50% more weld points. Generally, the number of weld points is increased because power when spot welding is different from the time of manufacture.

In the underframe there are sites where panels are put on top of each other. If the total panel thickness is more than 3 mm, choose MIG plug welding in preference to spot welding.

When MIG plug welding, the same number of points as on a new vehicle is fine.

In principle, the sites of the spot welds should be different from the sites on the old panel.

4) Preparation for welding

Cover the surrounding panels and glass with weld protection sheets so that they are not marked by sputters or sparks during welding.

When spot welding, use a part of an old panel or a piece cut off the new panel to test weld using the same material and panel thickness. Check the nugget shape and size and strength of the test piece.

■ Protective sheet

5) Tack welding

Weld not from the edge inward, but weld first at key points leaving a space in between. Remove the weld clamps when the panel stops moving.

Check reference measurements and arrangement. If there are no problems complete the welding.

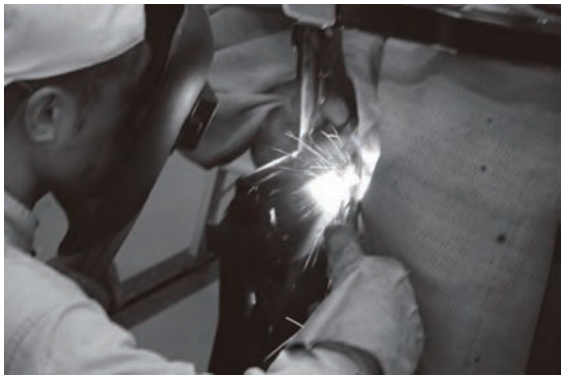
* Key points are corners and sites where the shape changes. For long parts key points are evenly spaced points. Weld alternately, rather than in one direction.

6) Welding

Fill in the spaces between the key points. As with sites where the panel has been cut out to be patched, once welds have been made at intervals weld the spaces in between.

The various spot welder arms and air clamps can be used effectively for different repair sites.

The basic rule is to use a MIG welder for any sites where spot welding is not possible.



Use spot and MIG welding as appropriate

7) After treatment

After welding, check the various measurements. Also check to see whether welding has caused any distortion.

Make a visual check of the weld sites to see whether the welds have adequate strength.

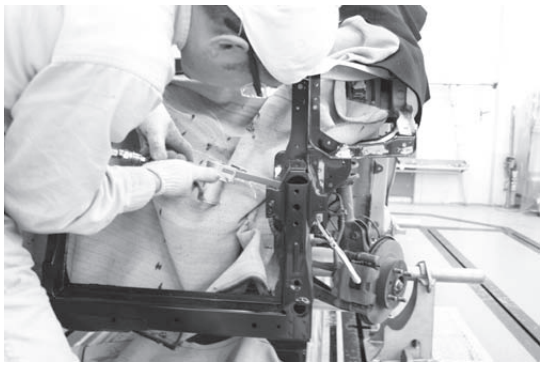
Use a disc sander or belt sander to smooth the surface of MIG plug welds and butt weld sites. Be careful not to grind too much.

Because the heat generated through MIG welding can cause distortion, if necessary repair using hammering.

Deburr spot welds using a sander also.

Then apply a sealer, antirust agent or foaming agent.

Apply more rustproofing than would be used for a new vehicle. This is because welding makes metal prone to rusting.



Smooth using a belt sander

3. Bonded panels

(1) Structural adhesives

There are two methods for bonding panels using a structural adhesive: ① using only an adhesive; and ② combining an adhesive and welder. The former method is called panel bonding while the second is called weld bonding.

Using an adhesive has the following advantages: ① stress is evened out; ② welded parts do not deform; ③ they have excellent water-tightness and air-tightness; and ④ it is easy to join different materials. The disadvantages are that thermal resistance and repeat bonding are not very good and hardening takes time. Bonding provides similar or superior strength to spot welding because unlike spot welding where spots are welded it is the surface that is joined.

(2) Bonding methods

When cutting out and making a patch, there are a number of methods depending on the repair site and strength. The two main methods are attaching a reinforcing panel to the under side of the join and welding, and making a flange to lap the join. In a flange operation, there are various lines, though this can also be remedied.

Because adhesives used for repair take time to harden the panels must be secured to a firm surface or clamped. This can be done in various ways. Methods include combining spot welding and rivets, using special fastening clamps and combining spot welding and adhesive.

When repairing panels using the bonding method, positioning must be precise and the panels must be securely fastened until the adhesive has hardened completely.

There are cases where due to a huge change in temperature the difference between the cut out sheetmetal and swelling or contraction of the filler after painting, making the line visible as a result. Ways to counter this include selecting an appropriate filler and thorough implementation of forced drying.

Long panels cut out and replaced are prone to distortion caused by heat. There is also a higher risk of rusting.

■ Example of weld bonding

① Attaching to the back of a panel

Make a piece with the same shape for attaching to the back of the body side and the side of the part being replaced and glue using adhesive.

Spot weld the first of the two pieces to be worked.

Fasten rivets on the surface of the second piece.

② Joggling

Make a joggle (slight step) on the side of the replacement part and glue it to the body using adhesive.

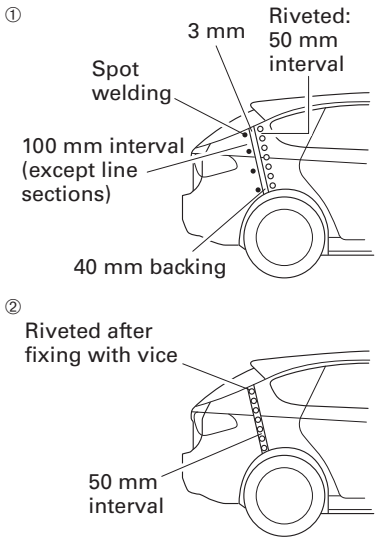
After clamping the cut surface with a special vice, fasten using rivets.

Use a flanging tool that can also be used on crowns and corners.

③ Standard panel replacement

Examples: Roof panel, door outer panel.

Advantage: Fewer weld points



Chapter 12 Repairing aluminum alloy and plastic panels

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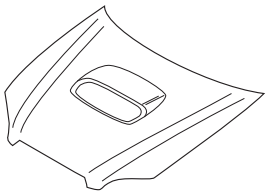
(2) Repair work 2
(3) Heating 2
(4) Welding 2
(5) Substrate treatment 3
2. Repairing plastic panels 4
(1) Minor damage 4
(2) Major damage 4
(3) Cracks and holes 5

1. Aluminum alloys

In Subaru vehicle bodies, aluminum alloys are used in the hood and the trunk lid.

■ The hood of the first Legacy (BP/BL) model was made from aluminum alloy



(1) Sanding

Aluminum alloys possess different properties to steel and though the same basic body repair methods are used, several precautions are required.

First, because the surface is soft, deep sanding marks are easily made.When removing paint, use paper with a finer grit size than paper used for sanding sheetmetal.

The surface of aluminum soon oxidizes and though no further corrosion occurs, paint does not adhere well to this oxidized film. Consequently, carry out surface preparation straightaway.

(2) Repair work

Only sites in aluminum alloy panels with elastic deformation can be repaired by panel beating. Repairing sites with plastic deformation is very difficult.

Strength is also lowered as a result of hammering and repeated pulling. Hammers leave marks and there is considerable stretching. Therefore, it is preferable to use a wooden or plastic hammer.

Also, when an aluminum alloy is in contact with iron, the aluminum will rust as a result of being in contact with another metal. An aluminum alloy may rust because of iron powder adhering to tools used everyday for sheetmetal.

There are stud welders that have special aluminum pins for use on aluminum alloys. The increasing use of aluminum alloy panels has seen the development of more and more equipment for aluminum alloys and most parts that are replaced can be repaired.

(3) Heating

When working with aluminum apply moderate heat as aluminum can break if force is applied under low temperatures. The right temperature is roughly the same as when you touch a surface wearing a heavy duty cotton glove and it feels hot.

Aluminum alloys are good conductors of electricity. Since the heat of a heated area spreads, make sure that only a small area is heated and that the temperature isn't too high.

Though aluminum is easy to repair because it doesn't crack when heated, there is a limit to how hot it can be heated, which if exceeded with lower strength. Despite some variation depending on the particular aluminum alloy, the threshold is 200 – 250 ˚C. Check the temperature with a contactless thermometer.

(4) Welding

Since aluminum alloys require a large current due to their electroconductivity, welding cannot be done using a spot welder used for repairs. There is a dedicated MIG welder that uses aluminum wire. If using this, use argon gas as the shield gas as you cannot use carbon dioxide gas.

(5) Surface preparation

Follow the same procedure as for sheetmetal: feathering, priming, and filling. Because some substrate paints can be used on aluminum alloy as well as sheetmetal and others are made for aluminum alloy only, check the paint manufacturer's specifications.

■ Pointers when repairing aluminum alloy

Grinding

Use paper with a finer grit size than paper used for sanding sheetmetal: ← Because it is softer
Once the substrate appears, immediately carry out surface preparation: ← prone to rust

Panel beating

Only possible for elastic deformation
Replace the part in case of plastic deformation
Use a wooden hammer or plastic hammer: ← Easy to stretch and to leave hammering marks
Development of repair tools are in progress: ← Studs, etc.

Heating

Easy to repair when heated
Temperature limits are 200 °C (6000 type alloy) and
250 °C (5000 type alloy): ← Excessive heating deteriorates strength.
Use a radiation thermometer

Welding

Use a dedicated MIG welder: ← Spot welding is impossible because of their electroconductivity.
Use aluminum wire and argon gas

Substrate

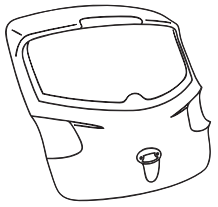
Primer for aluminum

2. Repairing plastic panels

In some instances plastic panels are used for the rear gate.

Examples of plastic bumpers often requiring repair are listed below.

■ Rear gate R1 (RJ)



(1) Minor damage

Wash damage affecting the luster caused by moderate contact, sand with P600 paper and then gently polish the damaged area.

(2) Major damage

If the bumper has scratches, wash with water and then cut off any protrusions with a knife. Sand with P120 – 600 paper.

(3) Cracks and holes

When repairing holes and cracks, fill the holes or cracks with a welding rod made from the same material using a welder used for plastic parts (heat gun).

After degreasing, cut a guide slit into the hole or crack, and create a V-shaped groove using a knife or sander. Sand the surface of the groove using P60 paper, degrease and clean.

Using a heat gun and a welding rod of the same material, fill in the groove while melting the damage site at the same time. Leave until it returns to room temperature. Hold the heat gun about 1 – 2 cm from the weld site, and fill in when the bottom of the welding rod and the damaged area melt together.

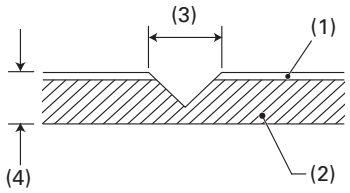
Check that it has returned to room temperature, and remove any excess from the surface using a knife or a cutting disc. If using a power tool, use at speeds of below 1,500 rpm. If the speed is too high the heat may cause melting.

Sand the surface with P240 paper.

Mask, degrease and clean.

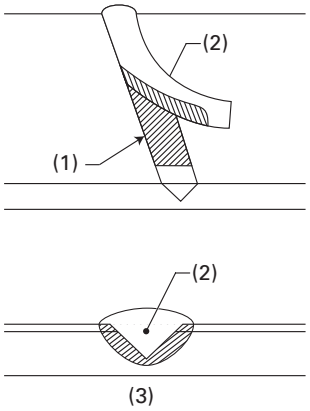
If the plastic is polypropylene, paint with a PP primer before starting the painting process.

■ Cut a guide slit



(1) Painting surface
(2) PP base
(3) 20 - 30 mm
(4) 3 mm

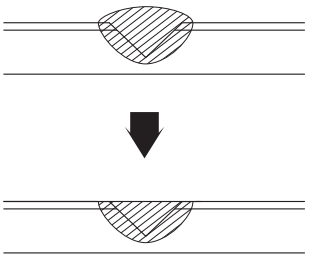
■ Fill in the groove using a heat gun



(1) Welding rod
(2) Area to be welded
(3) Cross-sectional view

- Melt the site shown by the shaded area
- To retain strength, do not melt until the welding rod starts to flow

■ Remove excess from the surface and sand with paper



Chapter 13 Quality inspection

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(1) Body and wheel alignment 2
(2) Factors and testing 2
2. Adjustments to electrical fittings and headlights **3**
3. Completion checks **3**
4. Panel arrangement **4**
5. Handling air tools **5**
6. Maintaining quality **5**

1. Wheel alignment

(1) Body and wheel alignment

The suspension determines the position of the wheels. In a unitized body, the suspension is attached directly to the body or via a subframe. Consequently, if there is deviation in the body, the wheels will also be misaligned. When the repairs have been completed, check the wheel alignment of vehicles that have had damage to the wheel apron and side frame.

The set values for wheel alignment are the same as those for a new vehicle. If the tires or wheel sizes have been changed the set values will be different. The values will also be different if the parts that make up the suspension are damaged or worn.

(2) Factors and testing

The factors in wheel alignment are toe-in, camber, caster and the kingpin angle. Misalignment or tilt in the front/rear vehicle axis is also an important factor that affects all four wheels.

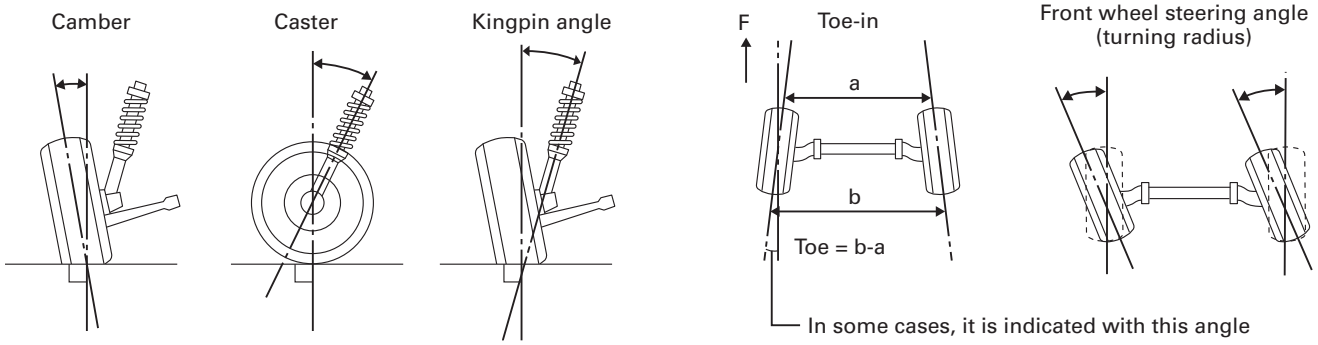
Use a four-wheel alignment tester under prescribed conditions (empty vehicle on horizontal site) to measure and test the wheel alignment. If there is misalignment, adjust while referring to the wheel alignment chapter in the Chassis edition of the service manual.

However, there are occasions when realignment exceeds the scope of adjustment, or adjustment is not possible for structural reasons. This requires alignment of the body to which the suspension is attached. Do this in accordance with the set values.

Areas at the front that affect wheel alignment the most are the area around the strut mounts and the area near where the front arm is attached. The wheel apron and the side frame are the panels that have the largest effect. At the rear, deformation of panels around where the suspension is attached affects alignment.

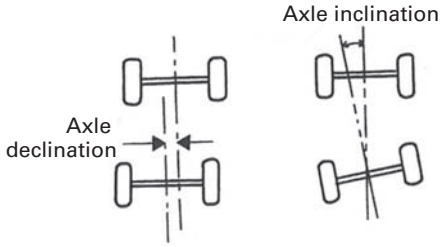
* Empty vehicle: Empty the trunk but fix the spare tire, jack and repair tools and fill up the fuel tank.

■ Main factors in wheel alignment



* The added angle between the camber and kingpin is called included angle

■ Ensure consistency for all four wheels



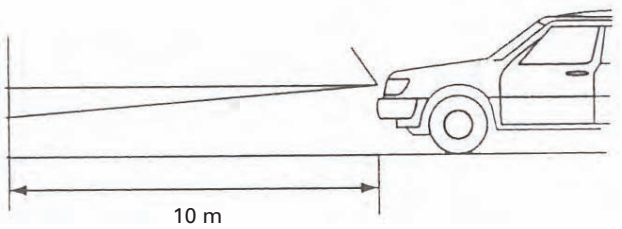
* Not only the individual elements, but the relationship of each position and balance are also important

2. Adjustments to electrical fittings and headlights

It is important to check the operation of the various electrical parts once repairs have been completed. Headlamps often have to be replaced in association with repairs, and also look out for incorrect connection and poor contact.

Safety regulations determine the direction and range of illumination for headlamps. When headlamps are removed and replaced as a result of repairing a radiator panel, test and adjust the headlamps using a headlamp tester while referring to the chapter on lighting systems in the Body edition of the service manual.

Height: Within 1/5
Right side: Right: 10 cm, Left: 20 cm
Left side: Left-right: 20 cm



3. Completion checks for repair sites

Make a visual check of the repair sites and adjacent panels to check weld finish and to see if bolts have been tightened.

Check for water leaks by hosing damaged vehicles that have had window glass and door weather stripping replaced and repairs to panels associated with the passenger compartment and the trunk.

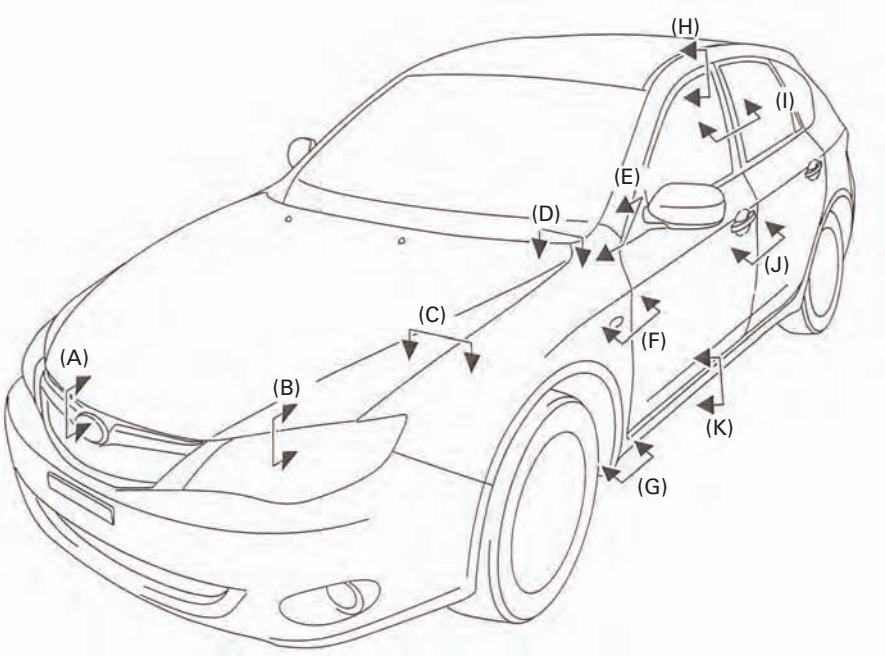
Road test all the cars when repairs have been completed, and check the operation of the engine, meters, transmission, brakes, steering, etc. Also check for any strange noises or vibration.

Drive carefully so as to avoid an accident.

4. Panel arrangement

Refer to the body repair manual for the reference values for the panel arrangement.

They are set taking adjacent panels into account, and there are cases where the gaps specified in the reference values cannot be rigidly maintained. Although there is some variation depending on the site, the permissible limit is ± 0.5 – 1.0 mm.



	Site	Reference value
(A)	Between front hood and front grille	6.0 ± 1.0 mm
(B)	Between front hood and headlamp	6.0 ± 1.0 mm
(C)	Between front hood and front fender	3.5 ± 1.0 mm
(D)	Between front hood and front fender (end only)	4.8 + 0.7 – 1.0 mm
(E)	Between front fender and front pillar	3.0 ± 1.0 mm
(F)	Between front fender and front door	4.0 ± 1.0 mm
(G)	Between front fender and side sill	3.0 ± 1.0 mm
(H)	Between roof and front door sash	5.0 ± 1.0 mm
(I)	Between front door sash and rear door sash	5.5 ± 1.0 mm
(J)	Between front door and rear door	4.5 ± 1.0 mm
(K)	Between front door and side sill	6.0 ± 1.0 mm

5. Handling air tools

Daily maintenance of air tools is vital so that they can be used when required.

① Use air at the prescribed pressure for each tool.

② Do not use tools for any other purpose.

③ Use clean air.

④ Clean, check and oil each tool as appropriate after use and at the end of the working day.

6. Maintaining quality

Maintaining quality is based on the established standard process and is achieved by repairers with recognized skills making repairs in accordance with the various manuals for devices, equipment and materials.

As a result, precision is further enhanced by getting a third party to check quality based on a checklist.

Appendices

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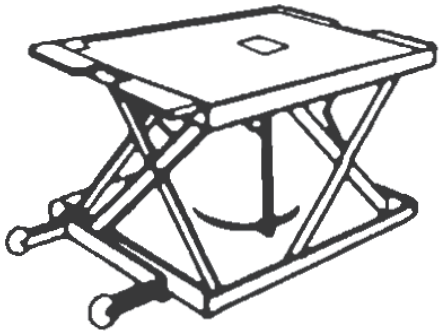
1. Auto body repair workshop equipment

The following are the main pieces of equipment and systems required by an auto body repair workshop equipment.

(1) Hoist

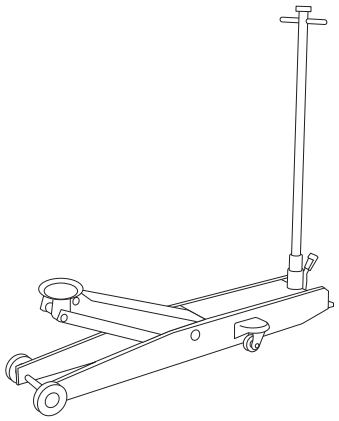
A hoist raises a vehicle using an electric motor or an air-powered hydraulic pump. They are not the same as hoists used for maintenance and many are pantograph hoists that are part of a body repair system. By raising a vehicle, the repairer does not have to assume unnatural postures while working on the side or underneath a vehicle. The basic rule is not to crawl under the hoist and to check for safety before and after use.



(2) Garage jack

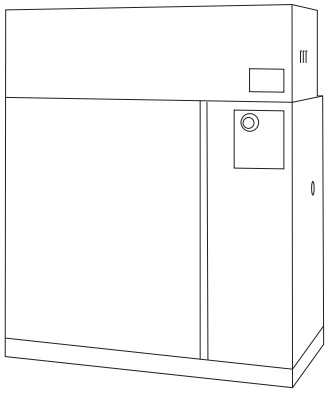
A garage jack uses manual power or air power to raise a vehicle.

Do not go under a vehicle that is raised on a jack. Be sure to support the vehicle with a rigid rack and check for safety.



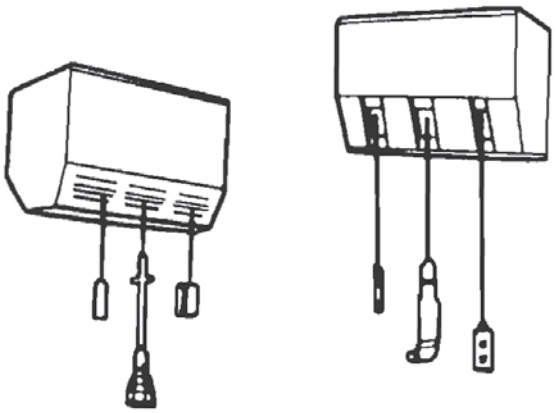
(3) Air compressor

Most power tools are driven by compressed air. A compressor operates using an electric motor. Although it depends on the number of repairers and the number of tools being used, the compressor should be set at 1.5 – 2.0 HP per individual repairer. Since work stops if the compressor shuts off, a reliable daily backup and maintenance system is required, including all of the air piping.



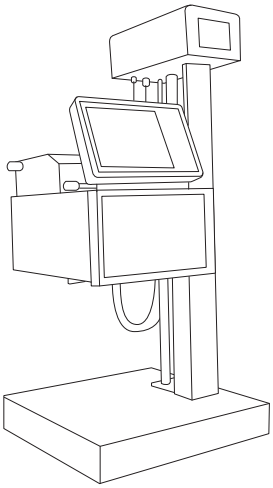
(4) Power supply unit

A power supply unit is a power supply system that integrates power supply, air and dust suction ducts. Many have a light that illuminates when the power is on. The unit is installed on the ceiling, a pillar or on a wall and cords and hoses can be pulled from the unit as needed.



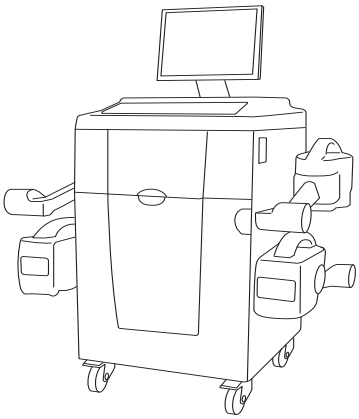
(5) Headlamp tester

A headlamp tester measures whether the illumination range of the headlamps conforms with standard.



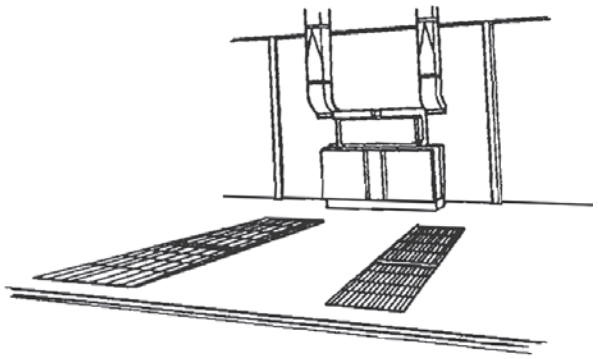
(6) Wheel alignment tester

Measures each of the factors for wheel alignment separately for each of the four wheels. It is also known as a four-wheel alignment tester. It can show differences between actual values and reference values.



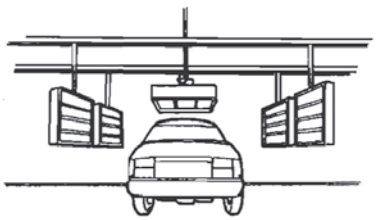
(7) Dust suction system

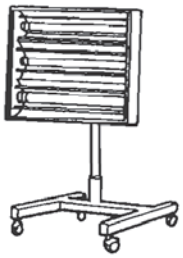
It sucks up and collects sand and dust generated when sanding body filler from the floor. When using a dust suction sander, put the tip of the hose into a gap in the mesh panel in the suction inlet in the floor. There are other portable cleaners (for one sander or several sanders), as well as dust collection systems with ducts in the ceiling or wall that collect dust from around 10 sanders.



(8) Drier

Accelerates putty drying. Driers have various heat elements, including infrared lamps and halogen lamps. They range in size from hand-held dryers to drier banks.





2. Related technical resources

When working on a model or a repair site for the first time, gather information by referring to technical resources on how to proceed with the repair work. Related items are as shown below.

(1) Body repair manual

Sites and materials

Plastic parts, zinc-plated sheetmetal, high tension steel

Rustproofing agent treatment sites

Sealers, rustproofing wax, undercoat

Panel components and cross-sectional diagrams of interlocking panels

Vehicle reference values and dimensions

Arrangement reference values

Weld points and cut lines for replacement of each panel

(2) Service manual - Body

Air bag removal and fitting, diagnosis

Removal and fitting of interior and exterior fittings

(3) Service manual - Chassis

Adjustment of suspension and wheel alignment